Rover Vos

From gameplay to comic book.
A generative artificial intelligence retelling tool that converts voice-recorded TTRPG sessions into a multimodal retelling format.

MASTER THESIS

submitted in fulfilment of the requirements for the degree of

Diplom-Ingenieurin

Programme: Master's Game Studies and Engineering

Branch of study: Retelling games with Artificial Intelligence

Alpen-Adria-Universität Klagenfurt

Evaluator
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Department of Information Technology

Klagenfurt, May 15, 2025

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Abstract

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Zusammenfassung

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List of Acronyms

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Chapter 1

workplace

1.1 Design Science Research

This thesis is based on the Design Science Research (DSR) methodology [2] and Computing as a discipline [1].

Computing as a discipline presents us with a framework for designing artefacts from an engineering point of view. It gives us four steps to solve a given problem:

1. State requirements
2. state specifications
3. design and implement the system
4. test the system

For the requirements of this thesis we need to very specific as the thesis is working with two different requirements at the same time. The main research question is looking for the requirements of a comic book generating artefact thus the requirements of the research project should be linked to finding these artefact requirements. But that means that the requirements of the artefact itself can not be part of the requirements of the research project. The artefact requirements are part of the conclusion of the the thesis.

1.1.1 Diverting from the DSR methodology

In DSR you should start

1.2 Retelling games

Most people play games during their personal down time and do not really think about games outside of leisure context (REF). However there are also a lot of people

that play games a lot and make it part of their lives. Looking at social media platforms like X, YouTube, Reddit, TikTok, etc. we can see that the sharing of gaming stories is a very big part of the internet. This sharing of stories can also be called retelling. Where people retell their personal stories about their gaming experiences. Retelling is not limited to games as the art of retelling is as old as humans and is a very big part of human culture(REF).

What is the essence of retelling?

When talking about game retelling

1.2.1 Difference between retelling and storytelling

1.2.2 State of the art of retelling

People share their gaming stories in many different ways. To have an holistic view of game retelling this section discussed the different forms of retelling video games.

Oldschool: talking Podcast YouTube Game play recording Podcasting Storytelling

An argument for Streaming. For completion sake I want to mention streaming and unedited playthrough videos here as well. Streaming is a weird one when it comes to retelling as it is not a retelling of an experience, but a live experience.

Reteller is an agent that produces and narrates a sequence of events, for the benefit of either human players or spectators[4].

Retelling is one of the largest if not the largest cultural phenomenon out there. I would even say that the retelling is one of the reasons the internet has become as big as it is. All forms of social media became the behemoths they are because of people retelling their lives. Academics would not exist if we did not retell everything we do in the form of papers, books, lectures, etc. For this thesis- it is important to know what retelling is, how people interact with it, what the core aspects are of a retelling and which moments of the gameplay session are important and should be part of the retelling.

Chapter 2

Introduction

2.1 Motivation and Objectives

Storytelling has a rich history of development starting back as far as humanity can go back. From Neandertals 40.000 years ago making cave drawings in an attempt to share experience and knowledge and 5000 years ago the ancient Egyptians made Hieroglyphics to tell stories and record history. To now YouTubers sharing their experience and people on TikTok are recording and sharing everything they can think of. The medium of storytelling has been innovated time and time again, cave drawings, Hieroglyphics, oral, written texts, printing press, photo, film, and everything now in the digital age. But where are we going next? In a world that is ever-changing, super time hungry and where people are looking for more and more ways to consume and share stories. What is the next form of storytelling? What are new forms of storytelling we can use with new technology? As we are at the advent of a great generative artificial intelligence revolution we should look into the possibilities of AI. How can we use generative AI to create the next form of storytelling?

This thesis aims to look into the possible applicability of generative artificial intelligence and (locally inferred) large language models in combination with game retelling. It will do this by recording Table Top Roleplaying Game (TTRPG) play sessions and using generative artificial intelligence to generate a comic book based on the recording of the players. Giving the players a new way of sharing their experience, a new way of retelling.

Retelling games in combination with artificial intelligence is a new field of research with a small research demand [4]. However with all the newest, easy to work with and well performing opensource generative models like Stable Diffusion [7] and Llama [9] there is a lot of potential for artificial intelligence as a reteller of games. As we can now generate images and text based on prompts and other input (like a voice recording) we can start to use artificial intelligence as a new form of storytelling. The printing press of the AI era.

This thesis started because of a small research demand for this topic in the academic world [4] and a direct request from my supervisor. For my motivation, I see a lot of potential in the usage of AI as a reteller of games. Primarily for video games, because you can track everything the player does and use that for generating. Besides video games, storytelling games like Dungeons and Dragons [10] and other TTRPG systems can also make great use of such a system. By recording a session and converting it with AI there is potential. TTRPGs are already a big part of the retelling on the internet through digital media like Twitch, YouTube and every podcasting platform out there. One of my favourite Dungeons and Dragons podcasts, The Adventure Zone, have converted their adventure into a comic book [5] and Critical Role even converted their story into a TV show [6]. Clearly there is a want for retelling TTRPG adventures. It is also a medium that leverages the usage of AI properly as there are infinite possibilities while playing TTRPG games and every group makes their own story. Thus the requirement for generative artificial intelligence goes up as there is no possible way of making a system that can incorporate everything people can do in a TTRPG game without generative AI.

The main research question of this thesis is: *What are the key design and implementation challenges of a multimodal generative AI tool for converting play sessions into multimodal retellings?* This

In conclusion, this thesis aims to explore the possibilities of generative artificial intelligence in the field of retelling games.

2.2 Structure

The basic outline of the research approach of this master thesis is to create an artefact which converts audio-recorded TTRPG play sessions into a comic book. The methodology that will be used is the Design Science Research methodology [2]. This methodology fits nicely with the research goal as it focuses on creating solutions through iterative development with a focus on testing the artefact. It also gives clear steps for both the design process and for a structured literature review which have been used as the skeleton of the thesis.

The first step is to identify the problem and the requirements of the system. This is done through a literature review and interviews with experts in the field. The second step is to design the artefact, which in this case is a tool that converts audio-recorded TTRPG play sessions into a comic book. The third step is to implement the artefact, which will be done using Python and various libraries for audio processing and comic book generation. The fourth step is to evaluate the artefact, which will be done through user testing and feedback from experts in the field. Finally, the fifth step is to communicate the results of the research, which will be done through this thesis and a presentation at a conference.

Chapter 3

Topic

3.1 Classification

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Slime Molds	
Systematics	
Classification:	Living organisms
Domain:	Eukaryotes (Eucaryota)
no rank:	Amoebozoa
Class:	Slime Molds
Scientific name	
Eumycetozoa (Zopf, 1884)	
Subclasses	
Dwarf slime molds (Protostelea) True slime molds (Myxogastrea) Cellular slime molds (Dictyostelea, Acrasia) Parasitic slime molds (Plasmodiophorina) Reticulate slime molds (Labyrinthulina)	

Table 3.1: Slime molds Systematics

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- Slime molds and animals:
  Slime molds, just like animals, can move independently. However, unlike animals, slime molds do not have limbs or a subdivision of the body.

- Slime molds and fungi:
  Slime molds, just like fungi, spread via spores. However, compared to fungi, slime molds have no mycelium (filamentous cells) and no chitin (used to form structure).

- Slime molds and bacteria/single-celled organisms:
  Slime molds usually have more than one nucleus, as is the case with bacteria and single-celled organisms.

Characteristics

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[1] I am a footnote

Figure 3.1: Plasmodium of Physarum polycephalum (R. Hoyer/Wikipedia. Creative Commons)

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3.2 Life Cycle

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Chapter 4

State of the Art

4.1 Retelling games

4.1.1 Examples of TTRPG retellings

4.1.2 Artificial Intelligence as a Reteller/storyteller

4.2 Comic books

Making Comic Books is an art form on its own and to understand how to generate a comic book with AI we need to understand how comic books function as an artefact: How they are made; How they are structured; How they are read; And what comic books are. This section will look at comic book studies to create a better understanding of comic book creation.

Comic books are a sequential art form[3]. When you take a comic book panel and look at it outside of the context of other panels it is just an image. But when you place them side by side in a sequential order the pictures become a comic book 4.1. Looking at the image we can see that an image of a man holding its hat is just a man holding a hat. But when you place two images of a man holding his hat side by side we can see that it creates a motion of tipping his hat.

4.2.1 Comic Book take aways

4.3 AI models

There are many different AI models that floating around the internet that are open source and could be useful for this thesis. The make choose between all the available models a requirement list has been constructed based on the artifact requirements. In short the Speech recording model needs to transcribe audio recordings to text. The LLM model needs to be able to generate a comic book script based on the transcribed text. Including a prompt for the generative image model and the the

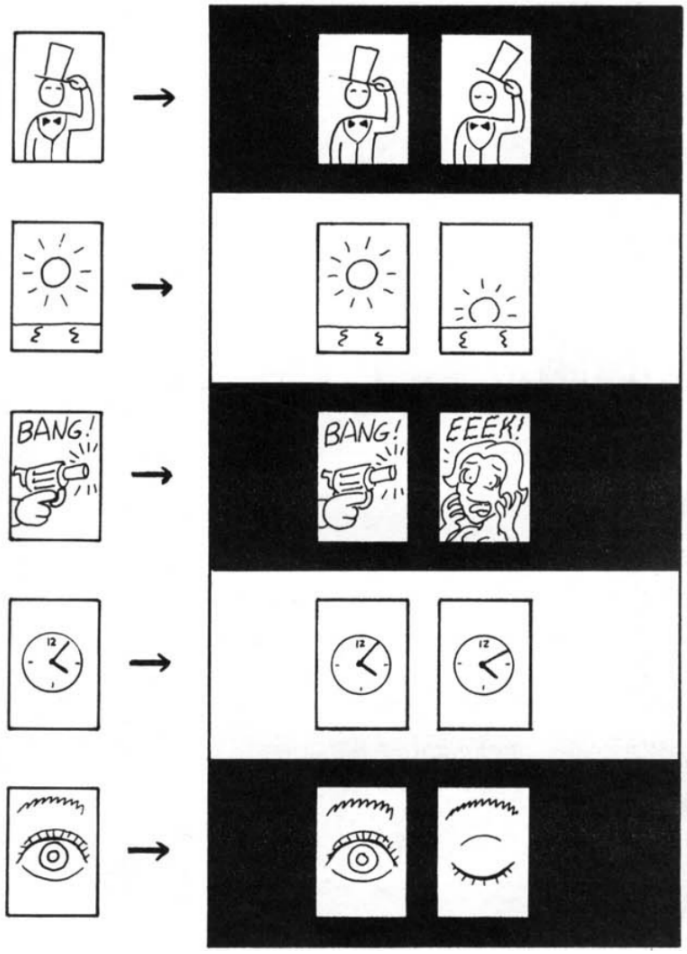

Figure 4.1: Sequential Art (Understanding Comics Scott McCloud page 5)

text that needs to be placed on the comic panels. The requirements: LLM Image generation Speech recognition

4.4 AI ethics

Chapter 5

Background and Methods

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5.1 Programs and Frameworks

5.1.1 Program 1

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5.1.2 Program 2

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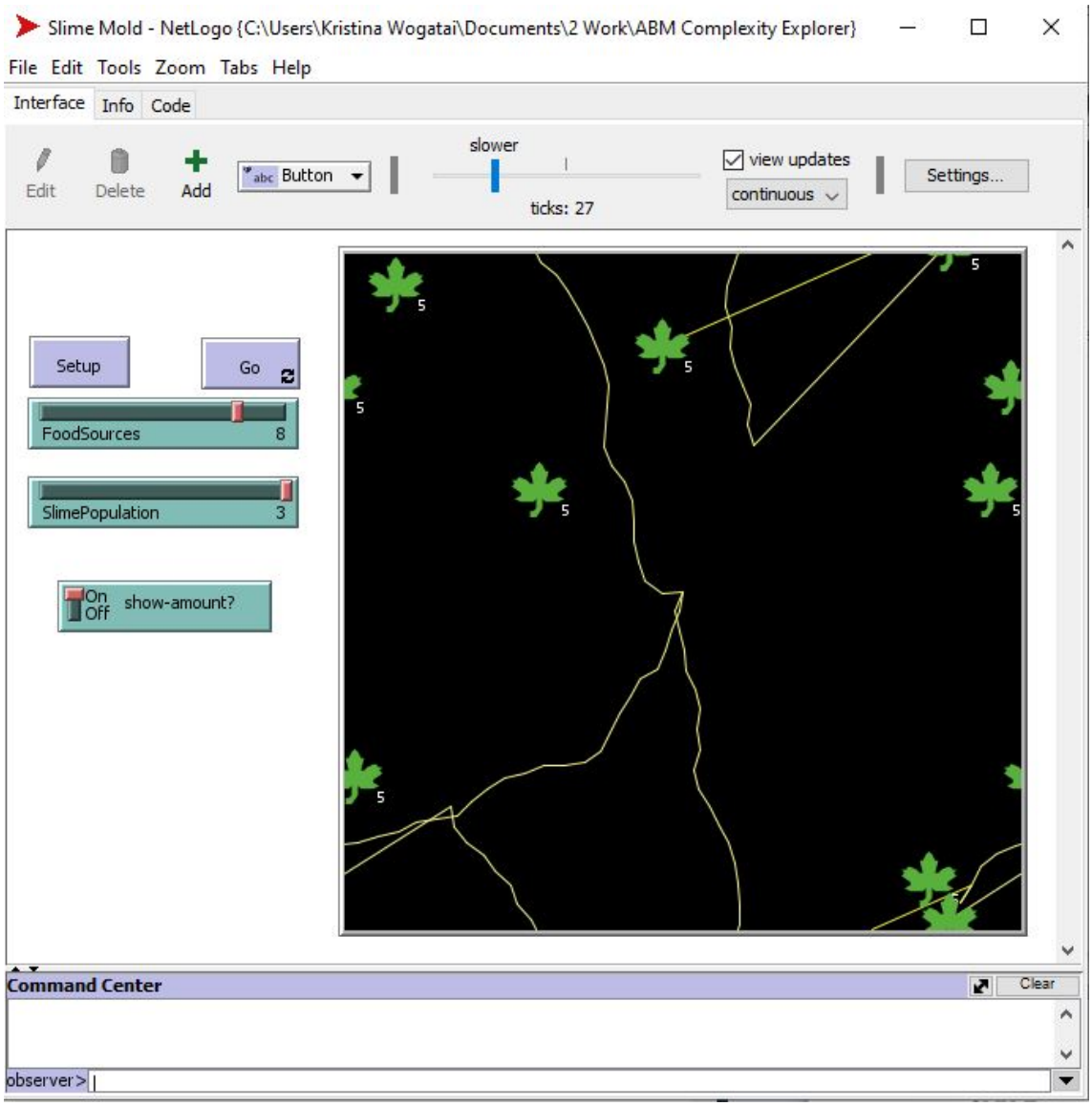

Figure 5.1: NetLogo sample program

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5.2 Models and Algorithms

5.2.1 Model A

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$$\overrightarrow{X(t+1)} = \begin{cases} \overrightarrow{X_b(t)} + \overrightarrow{vb} \cdot \left(\overrightarrow{W} \cdot \overrightarrow{X_A(t)} - \overrightarrow{X_B(t)} \right), r < p \\ \overrightarrow{vc} \cdot \overrightarrow{X(t)}, r \geq p \end{cases} \tag{5.1}$$

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$$p = \tanh |S(i) - DF| \tag{5.2}$$

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$$\overrightarrow{vb} = [-a, a] \tag{5.3}$$

$$a = arctanh(-\left(\frac{t}{maxt}\right) + 1) \tag{5.4}$$

Formula of $\overrightarrow{W}$:

$$\overrightarrow{W(SmellIndex(i))} = \begin{cases} 1 + r \cdot log\left(\frac{bF - S(i)}{bF - wF} + 1\right), condition \\ 1 - r \cdot log\left(\frac{bF - S(i)}{bF - wF} + 1\right), others \end{cases} \tag{5.5}$$

$$SmellIndex = sort(S) \tag{5.6}$$

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5.2.2 Sample Algorithm

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$$f(s) = g(s) + h(s) \tag{5.7}$$

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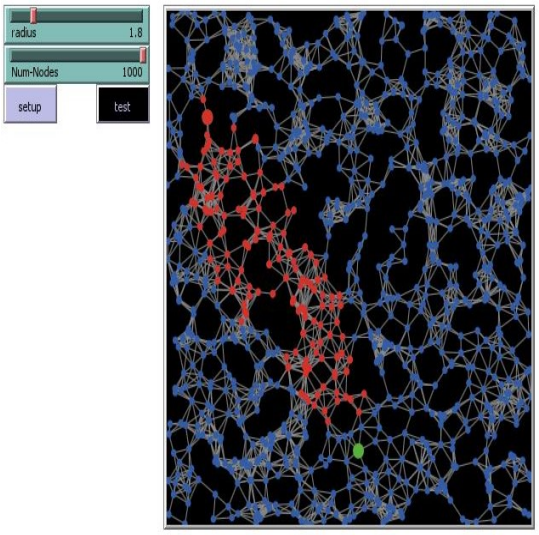

Figure 5.2: NetLogo - A* Simulation - Search

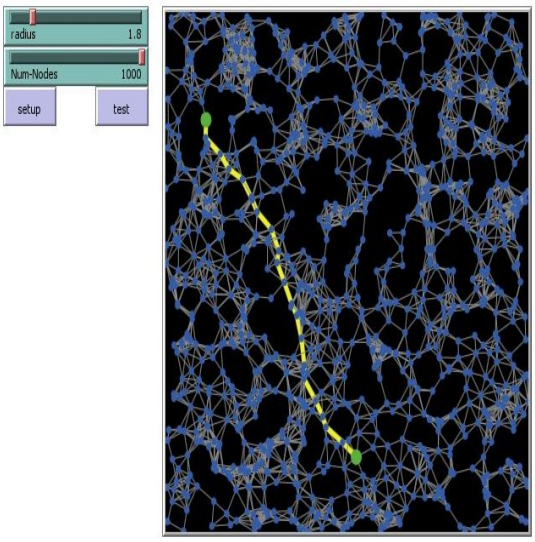

Figure 5.3: NetLogo - A* Simulation - Shortest Path

Chapter 6

Artefact Development

This chapter iterative design process of the artefact.

6.1 My Topic

6.2 Coding with Python

Python was the only language used in this project. This was chosen as Python is the go to language for programming with AI models (REF) and all major(if not all) models have python support.

Specifically python version 3.12.3 running on a the Windows Subsystem for Linux version 2 (WSL) running Ubuntu 24.04.2 LTS. WSL is a windows feature that allows you to run a Linux environment directly on Windows while in windows without having to run a virtual machine. You control the Linux distribution fully through the terminal.

6.3 AI models

6.3.1 Whisper

6.3.2 Llama

6.3.3 Image generating models: Stable Diffusion

The chosen image generation model is Stable Diffusion version stabilityai/stable-diffusion-xl-base-1.0 [8]

Chapter 7

Experiments

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7.1 Experiments and Simulations

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7.1.1 Materials and Methods

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7.1.2 Experiment 1: Title

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Experimental Setup

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tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et.

7.1.3 Experiment 2: Title

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Experimental Setup

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7.2 Results and Discussion

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Chapter 8

Conclusion

8.1 Summary

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8.2 Further Work

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8.2.1 Idea 1

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8.2.2 Idea 2

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Appendix A

NetLogo Code

A.1 NetLogo Main

A.2 SISMO NetLogo Main Function

```
__includes["math_functions.nls" "setup.nls"
    "network-creation.nls" "a-star.nls"]
;; 6 breeds needed in total, 3 for slime mold (plasmodia,
    pseudopodia, tubes), 1 for food source and 2 for A* algorithm
    ( networkpoints, searchers)
breed [ plasmodia plasmodium ]
breed [ pseudopodia pseudopodium ]
;; The tubes are used to indicate the shortest path between the
    center and the feed source
breed [ tubes tube ]
;; foods represent the foodsources
breed [ foods food ]
;; the networkpoints and searchers are used for the a*algorithm
breed [ networkpoints networkpoint ]
breed [ searchers searcher ]

globals [
  ;; to control the form of the visible chemical field
  scale-factor
  ;; sets the probability for pseudopodia to hatch a new
     pseudopodium
  hatch-probability
]

pseudopodia-own[
  ;; stores the path in a list of lists with x y coordinates
  path-list
```

```
]

foods-own [
  ;; each food source should have an amount of nutrients
  nutrient-value
  ;; the chemical level describes the radius of the food source
     in which the pseudopodia can perceive the food
  chemical-level
  ;; for the visibility of the chemical field
  intensity
]

tubes-own [
  ;; stores the path in a list of lists with x y coordinates
  path-list
]

searchers-own [
  memory                ; Stores the path from the start node to
     here
  cost                  ; Stores the real cost from the start
  total-expected-cost   ; Stores the total exepcted cost from
     Start to the Goal that is being computed
  localization          ; The searchers position
  active?               ; is the searcher active? That is, we
     have reached the node, but we must consider it because its
     neighbors have not been explored
]

patches-own
[
  light-level ;; represents the light energy from all light
     sources
]

;; setup, defines where to place which component of the
   simulation at the beginning and initialize the global
   variables
to setup
  ;; clear-all calls the clearing functions like clear-globals
     etc.
  clear-all
  ;; set global variables
  set hatch-probability 0.15
  set scale-factor 10
  ;; call make functions to create breeds
```

```
60    make-plasmodia
61    make-foods amount-foodsources
62    make-pseudopodia amount-pseudopodia
63    ;; next line is responsible for the visibility of the chemical
          concentration in the air
64    ask patches [ generate-field ]
65    ;; Resets the tick counter to zero, sets up all plots, then
          updates all plots
66    reset-ticks
67  end
68
69  to go
70    ifelse any? foods with [ nutrient-value > 0 ]
71    [
72      ask foods[
73        ;; There is a bug where food sources are created randomly
              and untraceable. This causes the pseudopodia to hang on
              this food source. Because it takes negative values and
              iterates forever. With this code this bug is fixed.
74        if nutrient-value < 0 [ die ]
75      ]
76      ask pseudopodia
77      [
78        let foodsource one-of foods-here
79        ifelse foodsource != nobody
80        [
81          let path-list-to-provide-to-tube path-list
82          ask foodsource
83          [
84            if show-nutrient-value [set label nutrient-value]
85            set nutrient-value nutrient-value - 1
86            if nutrient-value = 0 [
87              ;; create the network for the a star algorithm
88              create-pseudopodia-network turtle-set turtles-on
                    patch-ahead 0
89              ;; get one pseudopodia on the foodsource to set the
                    destination x,y coordinate for the a* algorithm
90              let one-pseudopodia-here one-of pseudopodia-here
91              run-a-star 0 0 ([xcor] of one-pseudopodia-here)
                    ([ycor] of one-pseudopodia-here)
92              die
93            ]
94          ]
95          ;; calculates a random float number between 0 an 1
96          if random-float 1 <= hatch-probability
97          [
```

```
98            ;; create new child from pseudopodia, replace the
                 zeros in the path-list to indicate, that it is a
                 copy
99            hatch-pseudopodia 1
100           [
101             let new-path-list replace-zeros path-list
102             set path-list new-path-list
103           ]
104         ]
105       ]
106       [
107         ;; movment of the pseudopodia -> bounce of the wall,
              movement and sense chemotaxis from food
108         bounce
109         wiggle
110         look-for-food
111       ]
112     ]
113     ;; if the a * buildet a tube display it
114     ask tubes[
115       let i 0
116       while [i < length path-list - 1]
117       [
118         let x-1 [xcor] of item i path-list
119         let y-1 [ycor] of item i path-list
120         setxy x-1 y-1
121         let col [pcolor] of one-of neighbors
122         set i i + 1
123       ]
124       die
125     ]
126     tick
127   ]
128   [
129     stop
130   ]
131 end
132
133 to look-for-food
134   ;; find chemotaxis in the area of a food source
135   let foodsource one-of foods in-radius 5
136   if (foodsource != nobody)
137   [
138     ;; if there is chemotaxis ahead move towards the center
139     face foodsource
140   ]
```

```
141 end
142
143 to wiggle
144   rt random 40
145   lt random 40
146   if not can-move? 1 [ rt 180 ]
147   fd 1
148   ;; create a new entry for the path list (with x and y
        coordinates and 0 because the step from this pseudopodia is
        new)
149   let xycoordinate (list xcor ycor 0)
150   set path-list insert-item (length path-list) path-list
        xycoordinate
151 end
152
153 to bounce
154   ;; bounce off left and right walls
155   if abs pxcor >= max-pxcor - 1
156   [
157     ;; if "at the end of the world" face towards center and move
          one forward
158     face patch 0 0
159     ;; move one forward otherwise it will get stuck at the edge
          of the world
160     fd 1
161   ]
162   ;; bounce off top and bottom walls
163   if abs pycor >= max-pycor - 1
164   [
165     ;; if "at the end of the world" face towards center and move
          one forward
166     face patch 0 0
167     ;; move one forward otherwise it will get stuck at the edge
          of the world
168     fd 1
169   ]
170 end
```

A.3 SISMO NetLogo Setup

```
1 ;;;;;;;;;;;;;;;;;;;;;;;;
2 ;; Setup Procedures ;;
3 ;;;;;;;;;;;;;;;;;;;;;;;;
4
```

```
;; create slime population
to make-plasmodia
  create-plasmodia 1
  [
    set size 5
    set shape "cloud"
    set color yellow
  ]
end

;; create pseudopodia
to make-pseudopodia [number]
  create-pseudopodia number
  [
    ;; for the pseudopias we need the same starting position as
       for the plasmodium. Because it spreads from the center
    set color yellow
    set shape "dot"
    set path-list []
    set path-list insert-item 0 path-list (list xcor ycor 0)
    pen-down
  ]
end

;; create food sources
to make-foods [ number ]
  create-foods number [
    set shape "circle 2"
    set color orange
    set size 2
    ;; create random coordinate
       https://ccl.northwestern.edu/netlogo/bind/primitive/random-float.html#:
    ;; If you want to generate a random number between a custom
       range, you can use the following format: minnumber +
       (random-float (maxnumber - minnumber))
    let randomxcoord (min-pxcor + 3) + (random-float ((max-pxcor
       - 3) - (min-pxcor + 3)))
    let randomycoord (min-pycor + 3) + (random-float ((max-pycor
       - 3) - (min-pycor + 3)))
    setxy randomxcoord randomycoord
    set nutrient-value 50 + (random (150 - 50))
    set chemical-level 23
    set intensity 50
    set label-color red
  ]
end
```

```
45
46 ;; patch procedure
47 to generate-field
48   set light-level 0
49   ;; every patch needs to check in with every light
50   ask foods
51     [ set-field myself ]
52   set pcolor scale-color orange (sqrt light-level) 0.1 ( sqrt (
       20 * max [intensity] of foods ) )
53 end
54
55 ;; do the calculations for the light on one patch due to one
     light
56 ;; which is proportional to the distance from the light squared.
57 to set-field [p]  ;; turtle procedure; input p is a patch
58   let rsquared (distance p) ^ 2
59   let amount chemical-level * scale-factor
60   ifelse rsquared = 0
61     [ set amount amount * 1000 ]
62     [ set amount amount / rsquared ]
63   ask p [ set light-level light-level + amount ]
64 end
```

A.4 SISMO NetLogo Network Creation

```
1 to create-pseudopodia-network [breeds]
2   ;; extract the pseudopodia breed from the agentset to access
      the list of pseudopodias
3   let pseudos [pseudopodia] of breeds
4   ;; iterate through all pseudopodias to check if they have an
      intersection
5   let coordinates-list [path-list] of item 0 pseudos
6   if length coordinates-list = 1
7   [
8     ;; in case there is only one pseudopodium
9     set coordinates-list lput item 0 coordinates-list
        coordinates-list
10  ]
11  let i 0
12  while [ i < length coordinates-list - 1]
13  [
14    ;; get current coordinates from all coordinates
15    let coordinates item i coordinates-list
16    let j length coordinates - 1
```

```
17      ;; we itarte backwards, to insert the intersection on the
            right place, otherwise it would mess up the order of the
            sequence
18      while [ j > 0]
19      [
20        if item 2 item (j - 1) coordinates != 1 and item 2 item
            (j) coordinates != 1
21        [
22          let x-1 item 0 item (j - 1) coordinates
23          let x-2 item 0 item (j) coordinates
24          let y-1 item 1 item (j - 1) coordinates
25          let y-2 item 1 item (j) coordinates
26          ;; Compare current pseudopodia with itself (to also
                calculate the interfaces of itself) and compare
                current with other pseudopodias.
27          ;; One doesn't need to compare pseudopodia one with
                pseudopodia two and than again pseudopodia two with
                pseudopodia one.
28          ;; Therefore iterate only for example pseudopodia two
                with three, four five and so on
29          let k i
30          while [ k < length coordinates-list - 1 ]
31          [
32            ;; get coordinates to compare from the list of all
                  coordinates
33            let coordinates-to-compare item k coordinates-list
34            let l length coordinates-to-compare - 1
35            while [ l > 0]
36            [
37              ;; if the coordinates are a copy of a parent skip
                    the comparison
38              if item 2 item (l - 1) coordinates-to-compare != 1
                    and item 2 item (l - 0) coordinates-to-compare !=
                    1
39              [
40                ;; Defining the comparison coordinates
41                let x-1-compare item 0 item (l - 1)
                      coordinates-to-compare
42                let x-2-compare item 0 item (l)
                      coordinates-to-compare
43                let y-1-compare item 1 item (l - 1)
                      coordinates-to-compare
44                let y-2-compare item 1 item (l)
                      coordinates-to-compare
```

```
45              ;; If the intersection points are already
                   connected, do not perform an intersection
                   calculation.
46              if (x-1 != x-1-compare) and (y-1 != y-2-compare)
                   and (x-2 != x-2-compare) and (y-2 !=
                   y-2-compare) and (y-2 != y-1-compare) and (x-2
                   != x-1-compare)
47              [
48                ;; calculate intersection points
49                let intersection-coordinate-result
                     intersection-point x-1 x-2 x-1-compare
                     x-2-compare y-1 y-2 y-1-compare y-2-compare
50                ifelse (intersection-coordinate-result != [])
                     and (intersection-coordinate-result != (list
                     0 0 1)) and (not empty?
                     intersection-coordinate-result)
51                [
52                  ;; if show-intersection-points is set, than
                       mark the intersection points with an X
53                  if show-intersection-points
54                    [
55                      hatch 1
56                      [
57                        set shape "x"
58                        set color red
59                        set size 1
60                        set xcor item 0
                             intersection-coordinate-result
61                        set ycor item 1
                             intersection-coordinate-result
62                      ]
63                    ]
64                  ;; The intersection point is set at the
                       correct position in the coordinates list
                       and the network around the intersection
                       point is built.
65                  ;; The network points are created only if
                       there doesn't exist a network point on this
                       coordinate.
66                  set coordinates insert-item (j) coordinates
                       intersection-coordinate-result
67                  set coordinates-to-compare insert-item (l)
                       coordinates-to-compare
                       intersection-coordinate-result
68                  ;; check if there are existing network points,
                       if not create some and link them, if they
```

```
                exist create the missing one and connect
                them
69              let first-point one-of networkpoints with
                [xcor = x-1 and ycor = y-1]
70              let intersec-point one-of networkpoints with
                [xcor = item 0
                intersection-coordinate-result and ycor =
                item 1 intersection-coordinate-result]
71              if(first-point = nobody)
72              [
73                hatch-networkpoints 1
74                [
75                  setxy x-1 y-1
76                  set hidden? not show-network
77                  set shape "circle"
78                  set size .5
79                  set color blue
80                  set label ""
81                  set first-point self
82                ]
83              ]
84              if(intersec-point = nobody)
85              [
86                hatch-networkpoints 1
87                [
88                  setxy item 0
                      intersection-coordinate-result item 1
                      intersection-coordinate-result
89                  set hidden? not show-network
90                  set shape "circle"
91                  set size .5
92                  set color blue
93                  set label ""
94                  set intersec-point self
95                ]
96              ]
97              ask first-point [create-link-with
                intersec-point]
98
99              let second-point one-of networkpoints with
                [xcor = x-2 and ycor = y-2]
100             if(second-point = nobody)
101             [
102               hatch-networkpoints 1
103               [
104                 setxy x-2 y-2
```

```
105                     set hidden? not show-network
106                     set shape "circle"
107                     set size .5
108                     set color blue
109                     set label ""
110                     set second-point self
111                   ]
112                 ]
113                 ask intersec-point [create-link-with
                      second-point]
114
115                 let first-compare-point one-of networkpoints
                      with [xcor = x-1-compare and ycor =
                      y-1-compare]
116                 if(first-compare-point = nobody)
117                 [
118                   hatch-networkpoints 1
119                   [
120                     setxy x-1-compare y-1-compare
121                     set hidden? not show-network
122                     set shape "circle"
123                     set size .5
124                     set color blue
125                     set label ""
126                     set first-compare-point self
127                   ]
128                 ]
129                 ask first-compare-point [create-link-with
                      intersec-point]
130
131                 let second-compare-point one-of networkpoints
                      with [xcor = x-2-compare and ycor =
                      y-2-compare]
132                 if(second-compare-point = nobody)
133                 [
134                   hatch-networkpoints 1
135                   [
136                     setxy x-2-compare y-2-compare
137                     set hidden? not show-network
138                     set shape "circle"
139                     set size .5
140                     set color blue
141                     set label ""
142                     set second-compare-point self
143                   ]
144                 ]
```

```
145                     ask intersec-point [create-link-with
                            second-compare-point]
146                   ]
147                   [
148                     ;; if there are no intersection points just
                           build the network without them for the
                           provided coordinates
149                     build-network x-1 y-1 x-2 y-2
150                   ]
151                   ;; Links are created between the network points
                         and these are then colored yellow to match
                         the rest of the simulation.
152                   ask links [set color yellow]
153                 ]
154               ]
155               set l l - 1
156             ]
157             set k k + 1
158           ]
159         ]
160         set j j - 1
161       ]
162       set i i + 1
163     ]
164 end
165
166 to build-network [x-1 y-1 x-2 y-2]
167   ;; check if there are existing network points, if not create
        some and link them, if they exist create the missing one
        and connect them
168   let first-point one-of networkpoints with [xcor = x-1 and ycor
        = y-1]
169   let second-point one-of networkpoints with [xcor = x-2 and
        ycor = y-2]
170   if(first-point = nobody)
171   [
172     hatch-networkpoints 1
173     [
174       setxy x-1 y-1
175       set hidden? not show-network
176       set shape "circle"
177       set size .5
178       set color blue
179       set label ""
180       set first-point self
181     ]
```

```
182   ]
183   if(second-point = nobody)
184   [
185     hatch-networkpoints 1
186     [
187       setxy x-2 y-2
188       set hidden? not show-network
189       set shape "circle"
190       set size .5
191       set color blue
192       set label ""
193       set second-point self
194     ]
195   ]
196   ask first-point [create-link-with second-point]
197 end
```

A.5 SISMO NetLogo Math Functions

```
1  ;; calculation of the intersection points (line-line
       intersection)
2  to-report intersection-point [x1 x2 x3 x4 y1 y2 y3 y4]
3    let point []
4    let t-numerator (x1 - x3) * (y3 - y4) - (y1 - y3) * ( x3 - x4)
5    let t-denominator (x1 - x2) * (y3 - y4) - (y1 - y2) * (x3 - x4)
6    let u-numerator (x1 - x3) * (y1 - y2) - (y1 - y3) * ( x1 - x2)
7    let u-denominator (x1 - x2) * (y3 - y4) - (y1 - y2) * (x3 - x4)
8    if (t-denominator = 0) or (u-denominator = 0) [
9      report point
10   ]
11   let t t-numerator / t-denominator
12   let u u-numerator / u-denominator
13   ;; there is an intersection if 0.0 <= t <= 1.0 and if 0.0 <= u
         <= 1.0
14   if (t >= 0) and (t <= 1) and (u >= 0) and (u <= 1)
15   [
16     set point (list (x1 + t * (x2 - x1)) (y1 + t * (y2 - y1)) 0)
17   ]
18   report point
19 end
20
21 ;; next two functions are for replacing the zeros in the
       coordinate list of a pseudopodium.
22 to-report replace-zero [the-list]
```

```
23   if item 2 the-list = 0
24     [ report replace-item 2 the-list 1 ]
25   report the-list
26 end
27
28 to-report replace-zeros [lists]
29   report map [ i -> replace-zero i] lists
30 end
```

A.6 SISMO NetLogo A* Algorithm

```
1  ; Auxiliary procedure to test the A* algorithm between two
       random nodes of the network
2  to run-a-star [x-start y-start x-end y-end]
3    ask networkpoints [set color blue set size .5]
4    ask links with [color = yellow][set color grey set thickness 0]
5    let start one-of networkpoints with [xcor = x-start and ycor =
       y-start]
6    ask start [set color green set size 1]
7    let goal one-of networkpoints with [xcor = x-end and ycor =
       y-end]
8    ask goal [set color green set size 1]
9    ; We compute the path with A*
10   let path (A* start goal)
11   ; if any, we highlight it
12   if path != false
13   [
14     highlight-path path
15     let tube-path []
16     foreach path [ x -> set tube-path lput x tube-path]
17     ;; hatch tube to make it visible
18     hatch-tubes 1
19     [
20       set path-list tube-path
21       set color yellow
22       set size 2
23       setxy 0 0
24       set pen-size 8
25       pen-down
26     ]
27   ]
28 end
29
```

```
30 ; Searcher report to compute the heuristic for this searcher: in
     this case, one good option
31 ; is the euclidean distance from the location of the node and
     the goal we want to reach
32 to-report heuristic [#Goal]
33   report [distance [localization] of myself] of #Goal
34 end
35
36 ; The A* Algorithm es very similar to the previous one
     (patches). It is supposed that the
37 ; network is accesible by the algorithm, so we don't need to
     pass it as input. Therefore,
38 ; it will receive only the initial and final nodes.
39 to-report A* [#Start #Goal]
40   ; Create a searcher for the Start node
41   ask #Start
42   [
43     hatch-searchers 1
44     [
45       set shape "circle"
46       set color red
47       set localization myself
48       set memory (list localization) ; the partial path will
           have only this node at the beginning
49       set cost 0
50       set total-expected-cost cost + heuristic #Goal ; Compute
           the expected cost
51       set active? true ; It is active, because we didn't
           calculate its neighbors yet
52     ]
53   ]
54   ; The main loop will run while the Goal has not been reached
      and we have active searchers to
55   ; inspect. Tha means that a path connecting start and goal is
      still possible
56   while [not any? searchers with [localization = #Goal] and any?
       searchers with [active?]]
57   [
58     ; From the active searchers we take one of the minimal
        expected cost to the goal
59     ask min-one-of (searchers with [active?])
         [total-expected-cost]
60     [
61       ; We will explore its neighbors, so we deactivated it
62       set active? false
```

```
63        ; Store this searcher and its localization in temporal
              variables to facilitate their use
64        let this-searcher self
65        let Lorig localization
66        ; For every neighbor node of this location
67        ask ([link-neighbors] of Lorig)
68        [
69          ; Take the link that connect it to the Location of the
                searcher
70          let connection link-with Lorig
71          ; The cost to reach the neighbor in this path is the
                previous cost plus the lenght of the link
72          let c ([cost] of this-searcher) + [link-length] of
                connection
73          ; Maybe in this node there are other searchers (comming
                from other nodes).
74          ; If this new path is better than the other, then we put
                a new searcher and remove the old ones
75          if not any? searchers-in-loc with [cost < c]
76          [
77            hatch-searchers 1
78            [
79              set shape "circle"
80              set color red
81              set localization myself ; the location of the new
                    searcher is this neighbor node
82              set memory lput localization ([memory] of
                    this-searcher) ; the path is built from the
83                                                                ;
                                                                      origin
                                                                      search
84              set cost c    ; real cost to reach this node
85              set total-expected-cost cost + heuristic #Goal ;
                    expected cost to reach the goal with this path
86              set active? true  ; it is active to be explored
87              ask other searchers-in-loc [die] ; Remove other
                    seacrhers in this node
88            ]
89          ]
90        ]
91      ]
92    ]
93    ; When the loop has finished, we have two options: no path, or
          a searcher has reached the goal
94    ; By default the return will be false (no path)
95    let res false
```

```
96    ; But if it is the second option
97    if any? searchers with [localization = #Goal]
98    [
99      ; we will return the path located in the memory of the
          searcher that reached the goal
100     let lucky-searcher one-of searchers with [localization =
          #Goal]
101     set res [memory] of lucky-searcher
102   ]
103   ; Remove the searchers
104   ask searchers [die]
105   ; and report the result
106   report res
107 end
108
109 ; Auxiliary procedure the highlight the path when it is found.
      It makes use of reduce procedure with
110 ; highlight report
111 to highlight-path [path]
112   let reduced reduce highlight path
113 end
114
115 ; Auxiliaty report to highlight the path with a reduce method.
      It recieives two nodes, as a secondary
116 ; effect it will highlight the link between them, and will
      return the second node.
117 to-report highlight [x y]
118   ask x
119   [
120     ask link-with y [set color yellow set thickness .4]
121   ]
122   report y
123 end
124
125 ; Auxiliary nodes report to return the searchers located in it
      (it is like a version of turtles-here,
126 ; but fot he network)
127 to-report searchers-in-loc
128   report searchers with [localization = myself]
129 end
```