

FirstName LastName

A Really Very Long Title in Title Case That Goes
Over Multiple Lines

MASTER THESIS

submitted in fulfilment of the requirements for the degree of

Diplom-Ingenieurin

Programme: Master's programme Information and Communications Engineering

Branch of study: Autonomous Systems and Robotics

Alpen-Adria-Universität Klagenfurt



Evaluator

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Institut für Vernetzte und Eingebettete Systeme

Klagenfurt, October 4, 2026

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Abstract

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Zusammenfassung

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Chapter 1

Introduction

1.1 Motivation and Objectives

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1.2 Structure

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Chapter 2

Topic

2.1 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 2.1: 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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¹I am a footnote



Figure 2.1: Plasmodium of *Physarum polycephalum* (R. Hoyer/Wikipedia. Creative Commons)

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2.2 Life Cycle

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Chapter 3

Related Work

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3.1 Maze Solving

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3.2 Behavioural Intelligence and Performance

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3.3 Transport Networks

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3.4 Routing Protocols

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$$\nabla^2\psi = \delta(x - x_i), \quad (3.1)$$

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3.5 Agent-based Modeling Approaches for Mobility Systems

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3.6 Slime Mold in Education

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3.7 Self-Organizing Networked Systems for Technical Applications

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Chapter 4

Background and Methods

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4.1 Programs and Frameworks

4.1.1 Program 1

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4.1.2 Program 2

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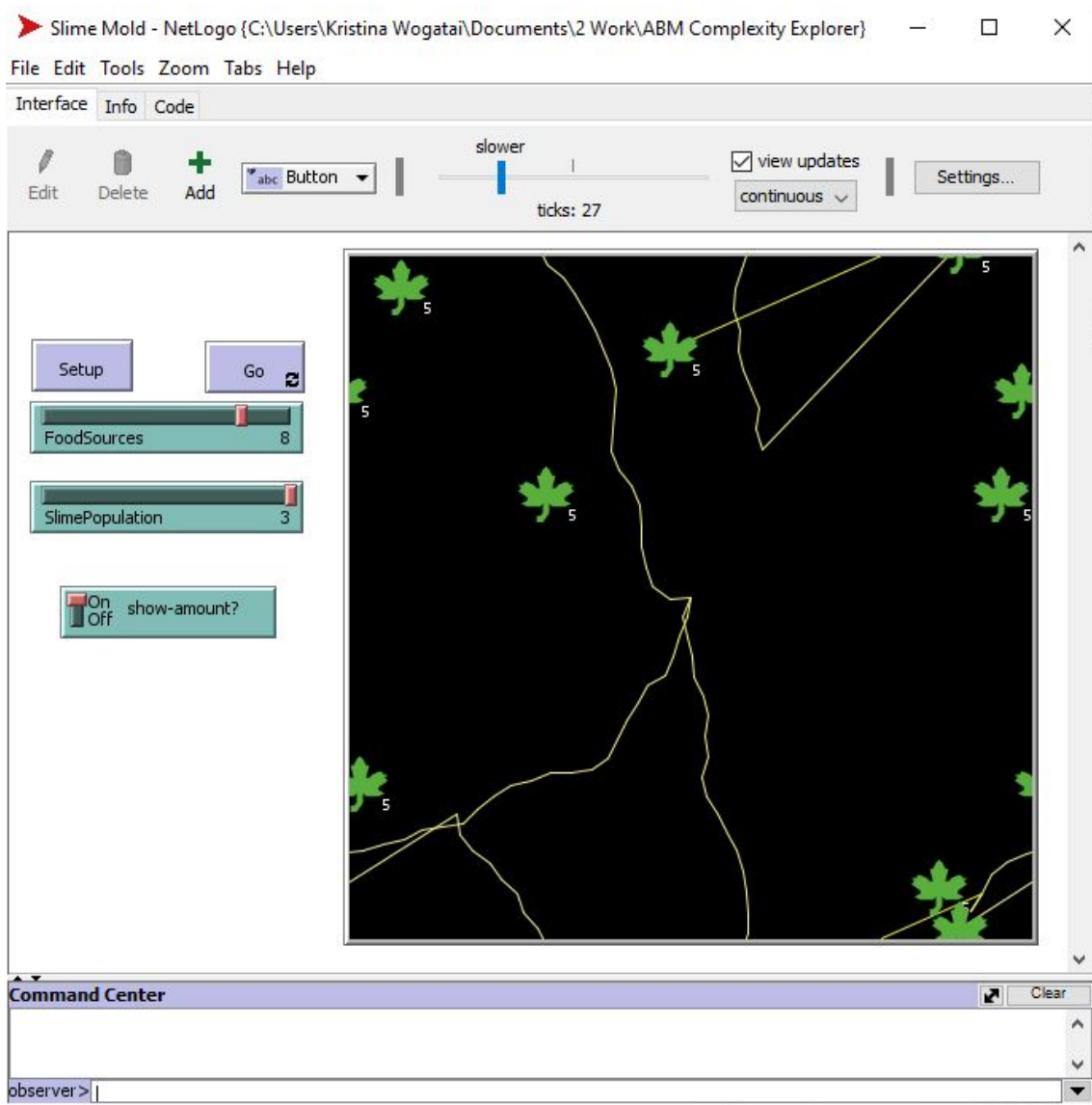


Figure 4.1: NetLogo sample program

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4.2 Models and Algorithms

4.2.1 Model A

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$$\overrightarrow{X(t+1)} = \begin{cases} \overrightarrow{X_b(t)} + \overrightarrow{vb} \cdot (\overrightarrow{W} \cdot \overrightarrow{X_A(t)} - \overrightarrow{X_B(t)}), r < p \\ \overrightarrow{vc} \cdot \overrightarrow{X(t)}, r \geq p \end{cases} \quad (4.1)$$

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$$p = \tanh |S(i) - DF| \quad (4.2)$$

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$$\overrightarrow{vb} = [-a, a] \quad (4.3)$$

$$a = \operatorname{arctanh}\left(-\left(\frac{t}{maxt}\right) + 1\right) \quad (4.4)$$

Formula of $\overrightarrow{W}$:

$$\overrightarrow{W(SmellIndex(i))} = \begin{cases} 1 + r \cdot \log\left(\frac{bF - S(i)}{bF - wF} + 1\right), condition \\ 1 - r \cdot \log\left(\frac{bF - S(i)}{bF - wF} + 1\right), others \end{cases} \quad (4.5)$$

$$SmellIndex = \operatorname{sort}(S) \quad (4.6)$$

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elit, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua.

4.2.2 Sample Algorithm

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$$f(s) = g(s) + h(s) \tag{4.7}$$

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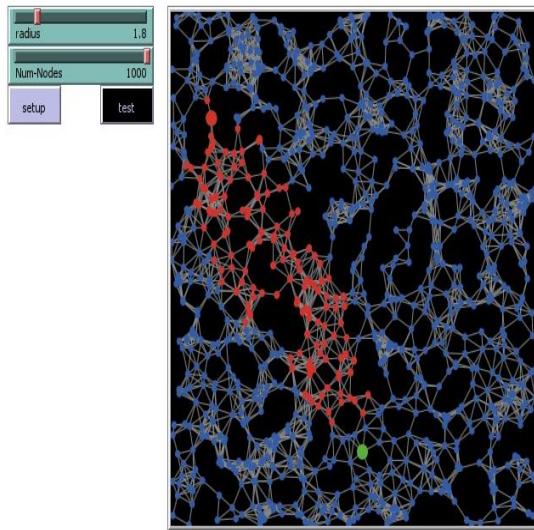


Figure 4.2: NetLogo - A* Simulation - Search

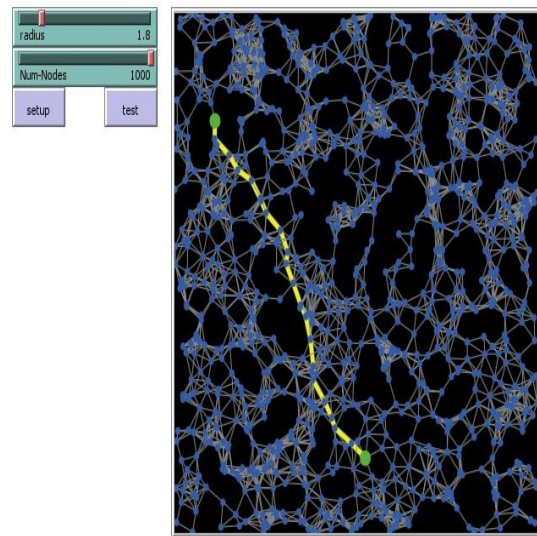


Figure 4.3: NetLogo - A* Simulation - Shortest Path

Chapter 5

Implementation

5.1 My Topic

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5.2 My Work

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5.3 My Implementation

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5.3.1 Initialization

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5.3.2 Setup

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5.3.3 Simulation Process

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Chapter 6

Experiments

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6.1 Experiments and Simulations

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6.1.1 Materials and Methods

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6.1.2 Experiment 1: Title

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Experimental Setup

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6.1.3 Experiment 2: Title

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Experimental Setup

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6.2 Results and Discussion

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Chapter 7

Conclusion

7.1 Summary

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7.2 Further Work

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7.2.1 Idea 1

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7.2.2 Idea 2

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Bibliography

Appendix A

NetLogo Code

A.1 NetLogo Main

A.2 SISMO NetLogo Main Function

```
1  __includes["math_functions.nls" "setup.nls"
2    "network-creation.nls" "a-star.nls"]
3  ;; 6 breeds needed in total, 3 for slime mold (plasmodia,
4    pseudopodia, tubes), 1 for food source and 2 for A* algorithm
5    ( networkpoints, searchers)
6  breed [ plasmodia plasmodium ]
7  breed [ pseudopodia pseudopodium ]
8  ;; The tubes are used to indicate the shortest path between the
9    center and the feed source
10 breed [ tubes tube ]
11 ;; foods represent the foodsources
12 breed [ foods food ]
13 ;; the networkpoints and searchers are used for the a*algorithm
14 breed [ networkpoints networkpoint ]
15 breed [ searchers searcher ]
16
17 globals [
18   ;; to control the form of the visible chemical field
19   scale-factor
20   ;; sets the probability for pseudopodia to hatch a new
21     pseudopodium
22   hatch-probability
23 ]
24 pseudopodia-own [
25   ;; stores the path in a list of lists with x y coordinates
26   path-list
```

```

23 ]
24
25 foods-own [
26   ;; each food source should have an amount of nutrients
27   nutrient-value
28   ;; the chemical level describes the radius of the food source
29   chemical-level
30   ;; for the visibility of the chemical field
31   intensity
32 ]
33
34 tubes-own [
35   ;; stores the path in a list of lists with x y coordinates
36   path-list
37 ]
38
39 searchers-own [
40   memory           ; Stores the path from the start node to
41                     here
42   cost              ; Stores the real cost from the start
43   total-expected-cost ; Stores the total expected cost from
44                     Start to the Goal that is being computed
45   localization      ; The searchers position
46   active?           ; is the searcher active? That is, we
47                     have reached the node, but we must consider it because its
48                     neighbors have not been explored
49 ]
50
51
52 ;; setup, defines where to place which component of the
53 ;; simulation at the beginning and initialize the global
54 ;; variables
55 to setup
56   ;; clear-all calls the clearing functions like clear-globals
57   ;; etc.
58   clear-all
59   ;; set global variables
60   set hatch-probability 0.15
61   set scale-factor 10
62   ;; 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

```

```

5 ;; create slime population
6 to make-plasmodia
7   create-plasmodia 1
8   [
9     set size 5
10    set shape "cloud"
11    set color yellow
12  ]
13 end
14
15 ;; create pseudopodia
16 to make-pseudopodia [number]
17   create-pseudopodia number
18   [
19     ;; for the pseudopias we need the same starting position as
20     ;; for the plasmodium. Because it spreads from the center
21     set color yellow
22     set shape "dot"
23     set path-list []
24     set path-list insert-item 0 path-list (list xcor ycor 0)
25     pen-down
26   ]
27 end
28
29 ;; create food sources
30 to make-foods [ number ]
31   create-foods number [
32     set shape "circle_2"
33     set color orange
34     set size 2
35     ;; create random coordinate
36     https://ccl.northwestern.edu/netlogo/bind/primitive/random-float.html#:
37     ;; If you want to generate a random number between a custom
38     ;; range, you can use the following format: minnumber +
39     ;; (random-float (maxnumber - minnumber))
40     let randomxcoord (min-pxcor + 3) + (random-float ((max-pxcor
41     - 3) - (min-pxcor + 3)))
42     let randomycoord (min-pycor + 3) + (random-float ((max-pycor
43     - 3) - (min-pycor + 3)))
44     setxy randomxcoord randomycoord
45     set nutrient-value 50 + (random (150 - 50))
46     set chemical-level 23
47     set intensity 50
48     set label-color red
49   ]
50 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 iterate 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 (1)
          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 recieves 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

```