ALGAE

Programmierpraktikum II SS 2000

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Contents

Chapter 1

Introduction

1.1 What is ALGAE

ALGAE is a followup system of elc (evolution, learning and communication), which is an implementation of a multi agent svstem (MAS) conceptualized and implemented by Roland Schwaiger and Konrad Lang. They investigate the evolution of wandering behavior of simple, reactive agents in a highly dynamic environment. Those simple agents wander based on the outcomes of feed forward ANNs (multi layer perceptrons). This system is implemented basing on the algae *Logopodium.*

1.1.1 Parameters

As a basic rule, each single parameter used for the simulation, the world or the agents, can be set by the user himself.

1.2 World of Algae

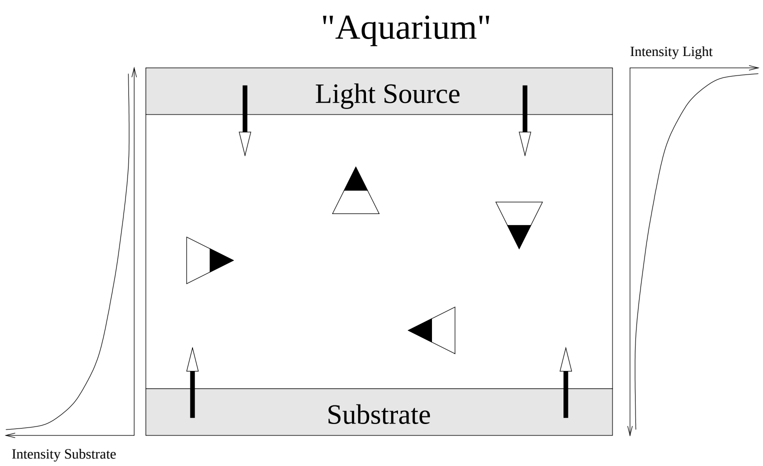


Figure 1.1: The world where our simulation takes place.

Our world where the simulation takes place is an two-dimensional aquarium. On the top resides a uniform light source and at the bottom there is some nutrition substrate. Algae (agents) live in the world between.

1.2.1 Light source

The light source is completely uniform, rays are sent from top to bottom in a straight line. The light source can be set to simulate a day/night cycle, but may also be set to a specific value during the simulation, or even turned off completely by the user. Light has a higher intensity at the top of the aquarium than at the bottom. Per default,the intensity is modelled by the function 1/y, where y represents the vertical world axis, but an other function may be defined by the user.
Agents reduce the light intensity for every spot below them, but they do not block the light completely due to a transparency value.

1.2.2 Substrate

Similarly conditions apply for the substrate which diffuses into the water. The distribution of substrate is based on a mathematical function. If a substrate particle is consumated, it is rebuilt after a specific amount of time. At bottom, substrate is rebuilt faster than above, because the source resides there.

1.3 Agents

Our agents, the algae, do not have a fixed life span. They live as long as they got an amount of energy greater than zero.

1.3.1 Energy

Every agent is 'born' with the same amount of energy. Energy is used for every action the agent may perform. If the energy level reaches zero, the algae dies. Energy may be regained through photosynthesis or substrate accomondation.

1.3.2 Sensors

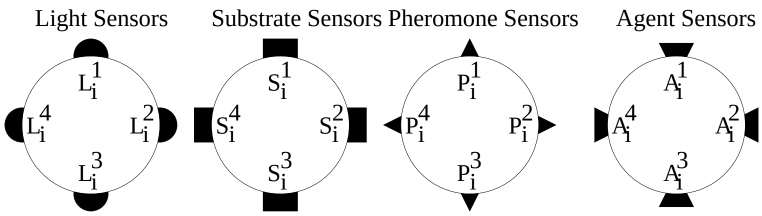


Figure 1.2: The various sensors of agents a_i.

To enable the agents to get information about their environment, we equip them with several sensors. An agent got four different sensors, each divided into four parts which

point to the main directions forward, right, left and backward. Therefore, the agent gets 16 different sensor inputs every timestep.
All sensor parts have a certain field of view (FOV) and a specific range. Due to the fact the strength of the input values from the various positions of the sensor parts differ, the agent should be able to detect where the source of signal is.

Light sensor

This sensor gets the summed light intensity of its FOV within its range.

Substrate sensor

This sensor gets the value of the substrate particles in its FOV. The value each particle adds to the sensor input depends on its distance.

Pheromon sensor

This sensor delivers the pheromon density in its FOV. The value each particle adds to the sensor input depends on its distance. Pheromons are released by the agents in order to find reproduction partners.

Bumper sensor

This sensor detects any obstacle (other agents or the world's border) around the algae.

1.3.3 Actions

An agent is able to perform an arbitrary amount of *different* actions every timestep of the simulation. All of these actions consume a different amount of energy. Of course, the agent won't perform actions that would use a higher amount of energy than it currently has.

Movement

Moving is probably the most important task an agent has to perform, in order to navigate to reproduction partners, towards substrate or higher light intensity. The agent may move once per timestep, with abritrary speed (up to its maximum speed). Movement with higher speed consumes much more energy than slow movement.
The agent always turns towards the direction it is moving - it cannot make some kind of sidestep.

Photosynthesis

One way for an agent to get energy is photosynthesis. The agent directly converts the light intensity at its current location into life energy. Higher light intensity produces a higher amount of energy.

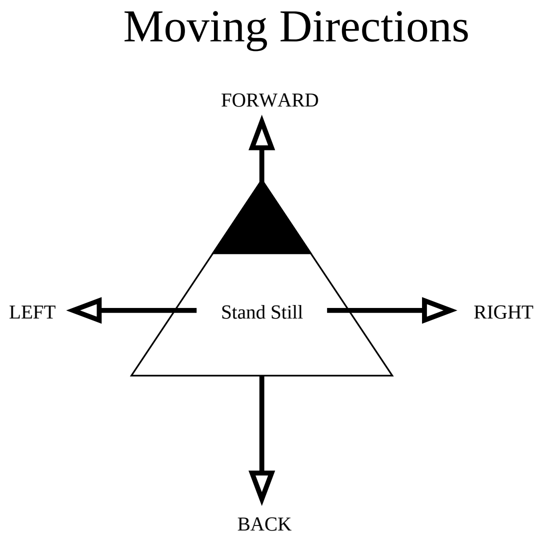


Figure 1.3: The possible moving directions of agent a_i.

Substrate acommomdation

If an agent is at the same location as a substrate particle, it consumes the particle and regains a specific amount of energy. The substrate is rebuilt after a certain number of timestep, depending on the y position.

Reproduction

If the energy level of an algae reaches a certain amount the algae may reproduce either sexually (meiosis) or asexually (mitosis).

- Meiosis, Pheromones
  Once an agent has collected enough energy it may reach a critical limit for sexual reproduction. From that moment on the agent may produce pheromone in order to signal other agents its ability for sexual reproduction. The agent will release the pheromone in its actual location. The pheromone will be apparent in the spot for given amount of timesteps.
  If one agent releases pheromone and meets another agent it will force the other one to reproduce, without taking care for the other's current energy level.

- Mitosis
  If an agent reaches a certain energy level before it finds a partner for meiosis, it reproduces itself asexually through the way of mitosis. This means the agent parts itself so we get two nearly identical individuals (they do not have exactly the same genotype because there is a certain mutation rate).

1.3.4 Neural Network

The various actions of an agent are partially determined by its mapping from input of the environment to output, i.e. reactions. This type of agent may be called reactive agent or stimulus/response agent. In our multi agent system we model this stimulus/response

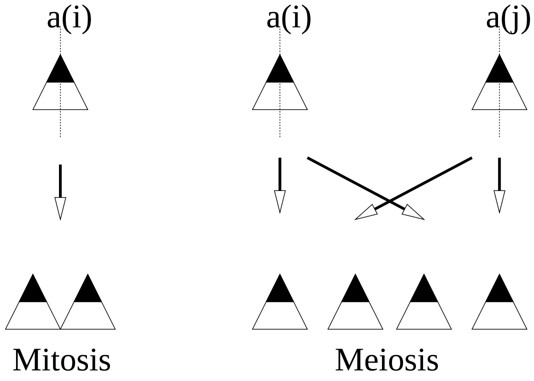


Figure 1.4: Reproduction of the agents a_i and a_j .

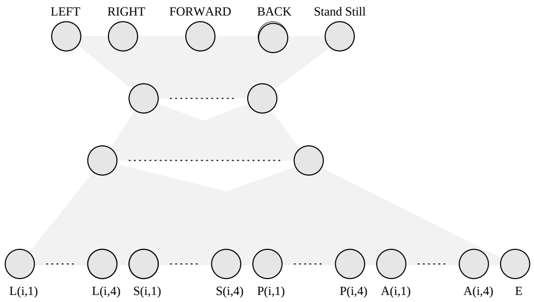


Figure 1.5: The ANN of agent a_i .

relationship by means of an artificial neural network – multi layer perceptron – (ANN). The input to the ANN consists of the sensor inputs and the energy level of the agent. Various hidden layers are used to perform transformations of the signals. Finally at the output level the calculated moving directions are shown.

Chapter 2

Deeper view to the problem

In this chapter, we want to deepen the understanding of the given task and concentrate on relevant parameters and notations of the problem under discussion.

2.1 The Simulation

Our task is to provide a simulation environment that sets the input to the ANN and performs the actions, shown by the output. This also should take care of reproduction methods and the death of an agent when out of energy. At last the simulation should be visualized.
At the beginning a certain amount of agents is randomly initialized. This includes the position and the heading as well as the neural network associated with each agent. This is the point, where the aquarium (the concrete matrix) gets initialized too. This includes the substrate distribution and the light, which are both set to a starting value. The pheromone level is set to zero at each point in the matrix.
After this global initialization, the main simulation loop is started. In that loop each agent performs some actions, which result from influences of its neighbourhood.

2.2 World

Basically, the world is responsible for controlling the experiment, some of its tasks are:

1. Set the output of the experiment in the GUI, i.e. show the agent, light distribution, substrate distribution, show details of the agents, s.a. energy level, genotype, phenotype.

2. Perform all calculations from one timestep t_i to timestep t_{i+1}, new agent positions[1], set sensor values of the agents[2]

[1]The agents perform their steps and request from the world their new positions, since only the world knows about the positions of the other agents. Furthermore, just the world knows about the concentrations (light, substrate, pheromone).

[2]This has to happen in the first phase of intervall $[t_i, t_{i+1}]$ since all further actions of the agents rely on the sensors values.

3. Insert new agents in the world once reproduction has taken place.
4. Remove agents with an energy level of zero (or below).

2.3 Aquarium

The aquarium has a two dimensional extension, specified by $(worldx, worldy)$. The borders on the left and right have a transparency factor of zero, i.e. no light may shine through the borders.

2.4 Light and Substrate

Let us denote the light distribution by $d_L(x)$ and the substrate distribution by $d_S(x)$. In the discussion above we have given an example for the distributions, namely $d(x) = \frac{1}{x}$. This is just one example and may be set by the user out of a given set of functions.

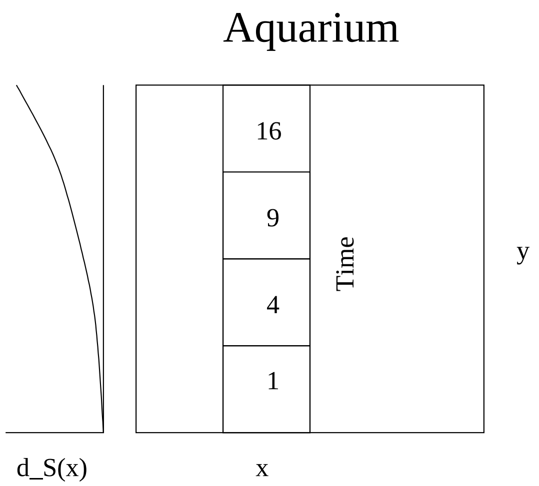


Figure 2.1: The concentration and distribution of the substrate, according to $d_S(x) = x^2$.

In figure 2.1 the distribution of the substrate is given. In each location (x, y) the substrate has concentration 1 or 0. Once a substrate is consumed by an agent the substrate will be rebuilt according to the given $d_S(x)$. In the given figure we have chosen $d_S(x) = x^2$, for $y = 3$ we get $d_S(3) = 9$ which are the timesteps the system needs to rebuild the substrate concentration[3].
Next let's consider the light distribution $d_L(x)$. Consider that an agent a_i in spot (x, y) blocks the light for all the agents a_j in locations $(x, y'), y' < y$. The light intensity will degrade according to a certain transparency factor τ_i of agent a_i.
In order to model day and night in the simulation $d_L(x)$ may depend on the time. As an example consider the sin function, as seen in figure 2.2. Further the time dependend modeling of the substrate concentration may be considered. The light intensity can also be changed manually by the user during the simulation.

[3] In a future release of the simulation the substrate concentration in (x, y) only may be rebuilt if there is a substrate concentration in locations $\{(x, y')|\forall y' : y' < y\}$

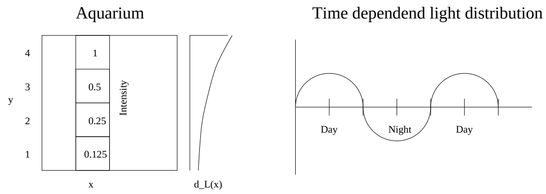


Figure 2.2: The concentration and distribution of the light, according to $d_L(x) = 1/x$.

2.5 Pheromone and Meiosis

How stated before, once an agent a_i has collected enough energy points it may reach a critical limit for sexual reproduction E_s. From that moment on the agent may produce pheromone in order to signal other agents its ability for sexual reproduction. Of course, producing pheromomes will reduce the energy level of the agent, let's denote the reduction ΔE_s. The agent will release the pheromone in its actual location[4]. The pheromone will be apparent in the spot for a given amount of timesteps, let's denote the amount of time by π_t.
For the case an agent has an energy level greater then E_s and it meets another agent we discussed various ways to consider meiosis.

1. To distinguish between the pheromones of different agents we may introduce two genders, male and female. The two genders release different kinds of pheromone. As can be seen easily, we reduce the probability of reproduction significantly.

2. Another way to consider pheromone of different agents we may intro two agent types. The first type just releases pheromone and the second agent type just senses pheromone. Apply the argument above.

3. If one agent releases pheromone and meets another agent it will force the agent to reproduce, no matter if the other agent has an energy level greater than E_s.

4. Finally, we introduce a flag for pheromone for each agent. With this method we get the possibility to differentiate between the pheromone of the various agetns and just agents with energy level greater than E_s may reproduce. Unfortunately not a biological plausible proposal.

In our simulation we will focus on the third possibility.

2.6 Artificial Neural Network

2.7 Evolutionary Cycle and Reproduction

As pointed out above we want to build our system based on the steady state approach, i.e. no generations are built and definite end is proposed but reproduction occurs on the fly. Basically all relevant information has to be encoded into various chromosomes (bitstrings).

[4] In future releases of the simulation we may consider some distribution function for pheromone release in the neighborhood of the agent

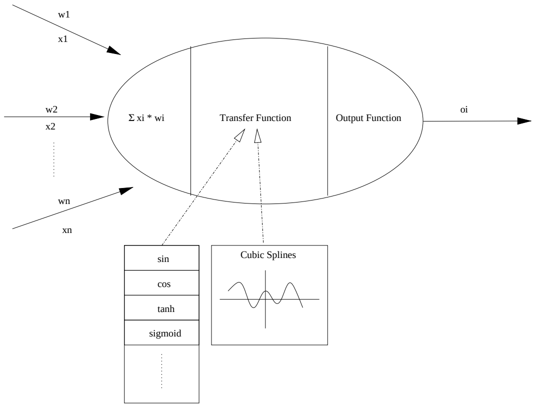


Figure 2.3: The detail view of one neuron in the ANN.

In our simulation we want to use three chromosomes per agent. The first chromosome C_1 encodes the topology (neurons and connections) of the ANN in a Modified Miller Matrix (MMM) manner. Basically the main diagonal of the connectivity matrix where an entry $m_{ii} = 1$ states that the neuron is present. Whereas entry $m_{ii} = 0$ states that the neuron is not present. If the entry is not in the main diagonal m_{ij}, where $i <> j$, then the entry states the existance of the connection from neuron i to neuron j.
The second chromosome C_2 encodes the weights of the connections and the biases of the neurons, two Bytes are used for encoding. The third chromosome C_3 encodes the cubic splines, where each point of the spline is encoded with its x and y coordinate, two Bytes respectively.

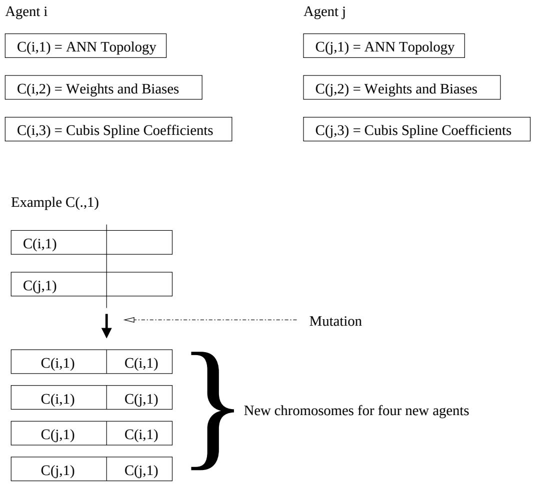


Figure 2.4: The details for crossing over between chromosome C_1 of agent a_i and a_j.

In order to reproduce we have to consider two different cases, meiosis and mitosis. In figure 2.4 we give an example for meiosis. In the mitosis case we duplicate the chromosomes and perform the same steps as in the meiosis case.

Chapter 3

GUI Description

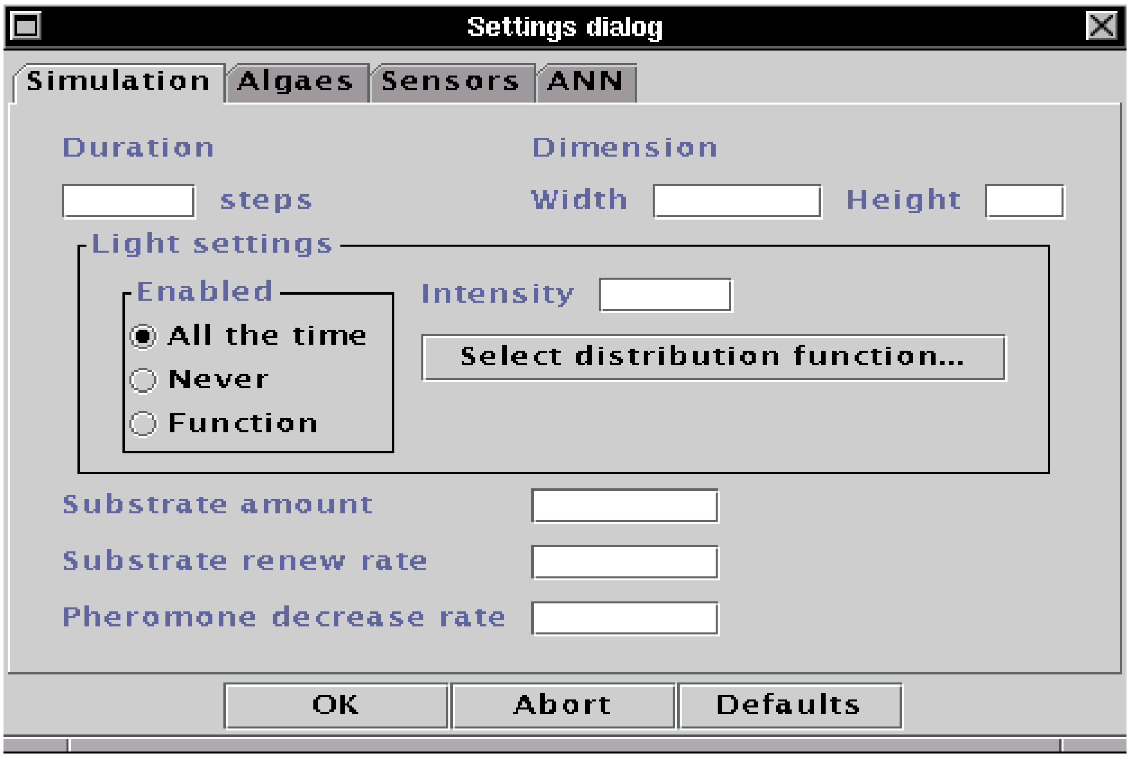
3.1 Configuration Window

The program starts with the configuration window, where all parameters relevant for the simulation are adjusted.
With the `OK` button the user accepts the adjustment and the configuration window will be closed and the Simulation window opens.
With the `Abort` button the user may abort the simulation.
The user can choose one of the pre-defined configurations using the `Default` dropdown list. Every adjustment can be saved in an own preset.

There are four tabstrips:

1. Simulation
2. Algaes
3. Sensors
4. Actions

3.1.1 Simulation



- The text field labeled `Duration` determines the duration of the simulation.
- The text fields labeled `Dimension Width` and `Dimension Height` determine the size of the aquarium.
- The three text fieldes at the end determine:

  the amount of substrate. (`Substrate amount`)

  after how many timesteps the substrate particles are renewed (`Substrate renew rate`)

  and after how many steps a pheromone disapears (`Pheromone decrease rate`)

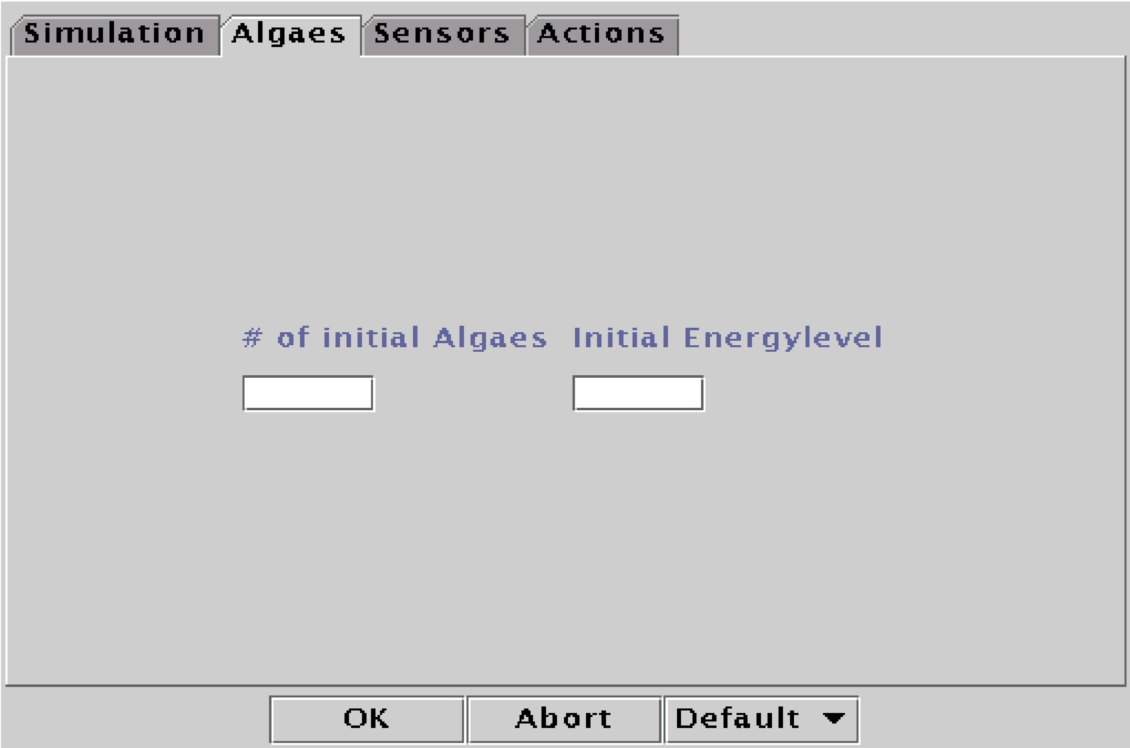
- In the frame `Light settings` there are
  - radio buttons labeled `Enabled` with the following possibilities:

    `All the time`, which means the light shines the whole simulation

    `Never`, which means the light doesn't shine at any time of the simulation

    `Function`, the light intensity is determined by a function.
  - a text field labeled `Intensity`, which determines the light intensity on the top of the aquarium.
  - and a button labeled `Select distribution function...`, where the user can select one of several light distribution functions

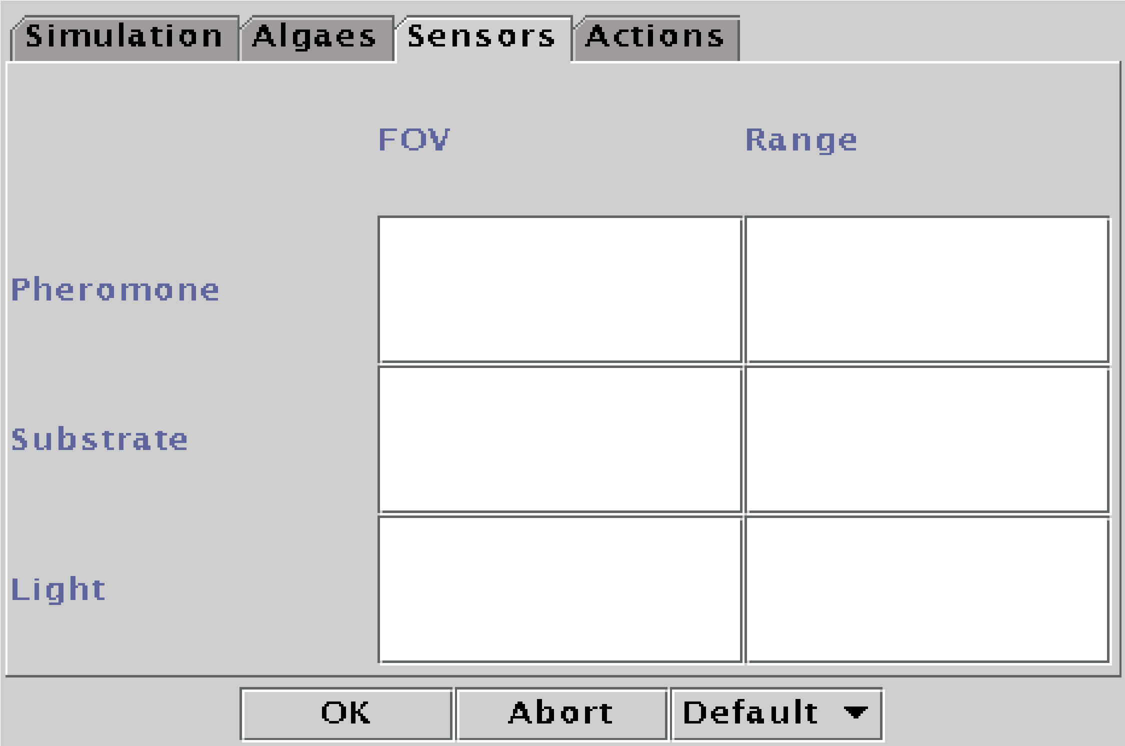
3.1.2 Algaes



In this tabstrip there are only two textfieldes (at the moment).

- The first textfield labeled `# of initial Algaes` determines the number of algae the simulation should begin with..
- The second textfield labeled `Initial Energylevel` determines the energylevel which the algae have at the beginning of the simulation.

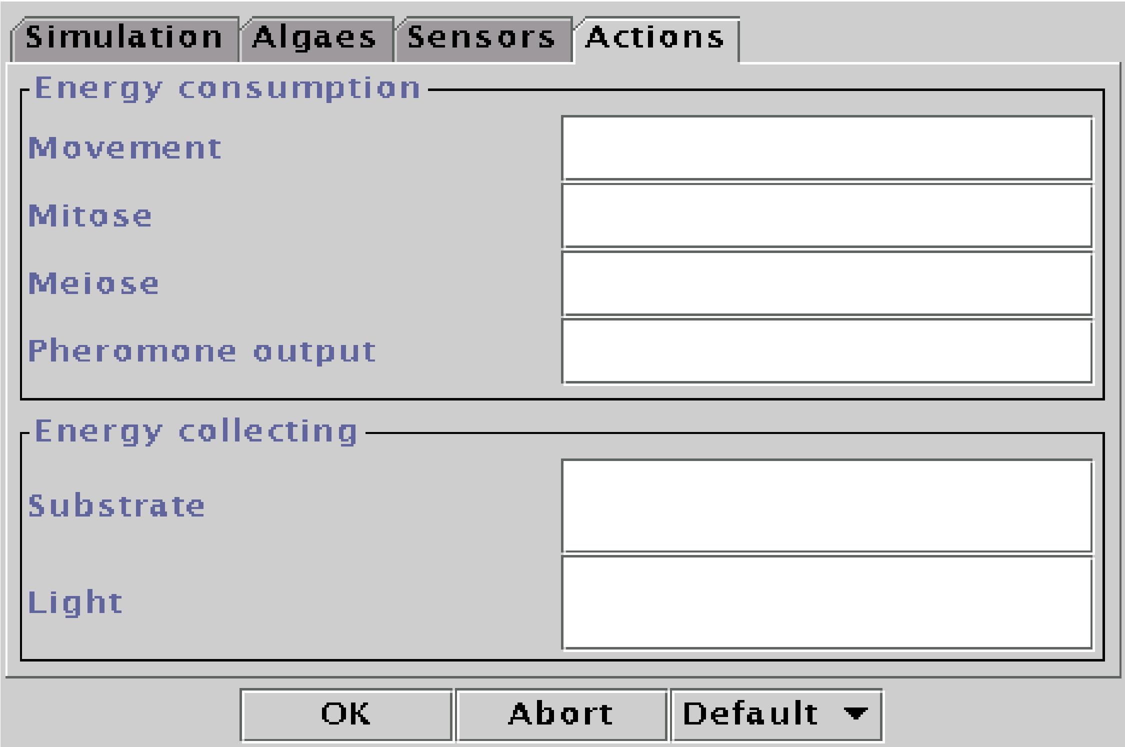
3.1.3 Sensors



In this tabstrip the user determines the adjustment of the three sensors (`Peromone`, `Substrate` and `Light`).

- `FOV` Field of View, this is the angle that the sensor field covers
- `Range` the range of the sensor

3.1.4 Actions



In this tabstrip are two frames:

- In the first frame labeled `Energy consumption` the user can determine

  How much energy an agent uses to move around (`Movement`).

  How much energy an agent uses to reproduce by Mitose (`Mitose`).

  How much energy an agent uses to reproduce by Meiose (`Meiose`).

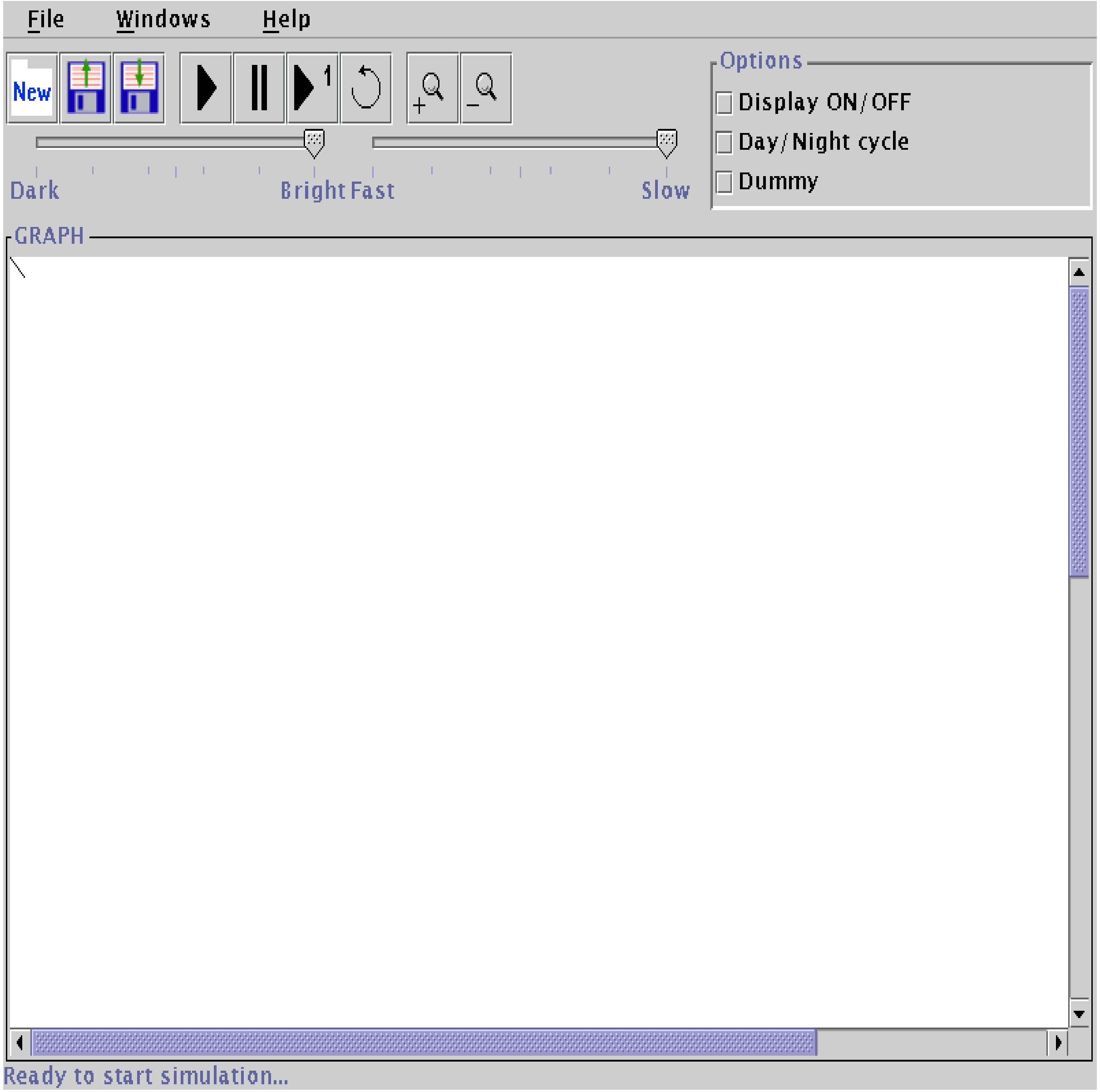
  How much energy an agent uses to discharge pheromone (`Peromone output`).

- and in the second frame labeled (`Energy collecting`) the user determines

  how much energy an agent gets from (`Substrate`)

  and how much energy can take up an agent from (`Light`)

3.2 Main GUI



3.2.1 Aquarium

This is the world where our simulation takes place. It shows the agents, pheromon tracks and substrate parts.

When the sim is paused, it is easy to select a specific agent; a new agent information window is opened then (see below)

3.2.2 MenuBar

File

1. `New` (starts a new simulation and resets the parameters)
2. `Load configuration` (loads another configuration)
3. `Save configuration` (saves the current configuration)
4. `Save sim status` (saves everything concerning the world and its agents)
5. `Load sim status` (opens a saved status)
6. `Quit` Closes the whole application.

Windows

1. `A list of all open windows - when one label is clicked, the active window changes to this`
2. `Show/hide simulation info window` (see below)

Help

1. `Help contents`
2. `About`

3.2.3 ToolBar

The important (e.g. the most used) parts of the simulation can be handled with the toolbar.

Buttons

- The first button starts the simulation new this means the parameters must be redefinied
  (this corresponds with `Menu, File, New`)
- The second button load a saved simulation status
  (this corresponds with `Menu, File, Load sim status`
- The third button saves the actual status of the simulation
  (this corresponds with `Menu, File, Save sim status`
- The fourth button starts the simulation at the beginning or if the simulation is paused.
- The fifth button pause the simulation.

- The sixth button is used to run the simulation step by step.
- The seventh button restart the simulation, that means the simulation starts new but the parameters remain the same.
- With the eighth button its possible to raise the zoom factor
- and with the ninth button its possible to lower the zoom factor

  (The possible zoom factor should be, from 1 pixel for each algae to a 10*10 pixel view.)

Delay sliders

There are two delay sliders:

- The first slider controls the intensity of the light source (from `Dark` no light to `Bright` much light).
- The speed of the simulation is controlled by the second delay slider (from `Fast` to `Slow`).

Check buttons

With the check buttons labeled `Options`:

- the graphic output can completely be turned of with the `Display ON/OFF` switch.
- To simulate the day/night cycle, the delay slider `Dark Bright` can be disabled with the `Day/Night cycle` switch.
- The `dummy` switch is only a substitute symbol at the moment.

3.2.4 StatusBar

By default, it shows the current number of agents and the elapsed time. When a specific point in our world is selected, we get the following information:

- Is there substrat at this place ?
- Are any phermomon tracks here ?
- Light intensity at this place ?
- The XY Position ?

3.3 Agent Information Window (n/a yet)

- Current sensor values
- The neural network
- The agent's genotype (bitstring)
- The speed, direction and action (i.e. eating) of the algae
- The energy level, age and current position
- Other information ?

3.4 Simulation Information Window (n/a yet)

Here we get several statistics about the status of our population and the simulation itself.

Appendix A

Session logs

A.1 March 15, 1999

Time: 17:00 - 17:30
Place: Room 202.2, Institute for Computer Sciences, University of Salzburg
Present persons: R. Schwaiger, C. Bauer, P. Eisenmann, T. Frommwald, M. Liedlgruber and D. Kadir

Treated points:

- Formalities
- General introduction to the problem

Tasks to perform until March 22,2000

- Get photos for the project-homepage
- Have a careful look at the document
- Have a look on JAVA

A.2 March 22, 2000

Time: 17:00 - 17:30
Place: Room 202.2, Institute for Computer Science, University of Salzburg
Present persons: R. Schwaiger, C. Bauer, P. Eisenmann, T. Frommwald, M. Liedlgruber and D. Kadir

Treated points:

- We have a concrete matrix where the simulation should take place
- Substrate

  Distribution of substrate is based on a mathematical function

  There is a specific amount of the substrate at every point in our matrix

The regeneration of the substrate depends on the distribution function and a basic time period (determined by some parameters)

- Sensors

  The sensors of our agents have a specific range and an angle of 'sight'. These things are variabel.

  We got a new sensor that can detect contact (with the wall or other agents)

- Pheromons disintegrate after a while

- Possible agent actions: Power consumption, movement, pheromon output, reproduction

  All actions consume different amounts of energy

- Energy consumption through photosynthesis or substrat accomondation

- Movement

  Speed ?

  Agents may move one unit in one time unit

- Reproduction

  Meiose / Mitose

  If the agent wants to reproduce through meiose he has to have a certain amount of energy. The agent follows the pheromon tracks of other agents and puts out pheromons himself.

- Pheromon output

  During movement

  The agent should not follow his own pheromon track

- Simulation steps

  The current status of the sim is displayed after each simulation step

  During one step the agents may perform an arbitrary amount of actions (exception: movement !)

Tasks to fullfill until March 29, 2000

- Prepare further questions

A.3 March 29, 2000

Time: 17:00 - 17:30
Place: Room 202.2, Institute for Computer Science, University of Salzburg
Present persons: R. Schwaiger, C. Bauer, P. Eisenmann, T. Frommwald and D. Kadir

Treated points:

- Agent input

  We need another input for our neural network: the current energy level of the agent

  It is probably necessary that agents know whether the detected pheromon is their own or not

- The neural network

  There are units in the ANN which are connected through weighted lines

  The more important the connection of two unit becomes, the thicker the connecting line.

  Output consists of the movement direction and everything concerning reproduction

- The light

  Probably there will be some sort of 'fight' for the positions that are near the light

  Agents that are not on top level will get less light (shadows)

  For this reason they may try to consume more of the substrate - the according connecting line of the ANN gets thicker

- How could the agent learn that sexual reproduction is better than the mitose ?

Tasks to fullfill until April 12, 2000:

- Revise the paper:

  Exact problem definition

  Session logs

  Discussions

A.4 April 12, 2000

Time: 17:00 - 17:30
Location: Room 202.2, Institute for Computer Sciences, University of Salzburg
Present persons: R. Schwaiger, P. Eisenmann, T. Frommwald, M. Liedlgruber and D. Kadir

Treated points:
(document revised:)

- Light/Substrate:

  Diffusion: Substrate regenerates faster at the bottom than above.

  Agent has transparency factor.

- Pheromon, Mitose, Meiose:

  Pheromon is placed only at the point, were agent is situated;

  time-delayed pheromon reduction.

  4 various ways to consider meiosis - we choose the 3rd one: forced reproduction.

- World(object):

  Output over all partial aspects.

- ANN:

  Processing of signals with 'Cubic Splines-Methode'(set points to calculate a function)

  In the ANN 'the winner takes all' - the maximum evaluated response is selected

Tasks until Mai 2, 2000

- first GUI (/World)-prototype
- create UML-model
- ev. other questions

A.5 May 2, 2000

Time: 17:00 - 17:30
Location: Room 202.2, Institute for Computer Science, University of Salzburg
Present persons: R. Schwaiger, C. Bauer, P. Einsenmann, T. Frommwald and D. Kadir

Treated points:

GUI Interface

- Saving

  Possibility of saving from intermediate stages

  To draft on a particular step of the simulation

- Buttons, menu bar and tabstrip

  "Settings" in the menu bar is problematic

  Button for gradual running

  Rename "Main" by "Aquarium"

New tabstrip which shows a list of all algae and the possibility to select one of them

Move the "ANN Sensors" tabstrip into the algae tab writer

A new menu point "Windows" which shows the details of the agents.

- others

  Show light and substrate in the aquarium.

  Possibility to hold back indication for a certain amount of steps

Tasks until May 24, 2000

- Description of the GUI Interface
- Some agents should move in the aquarium
- Think about in which information we would be interested
- Make treated changes of the GUI