SYSC5807 Assignment 2
Daisyworld

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Overview

This report covers the implementation of a Cell-DEVS model of the Daisyworld example showing the Gaia theory in action. Daisyworld shows the effect of planetary life on the planet's climate. Daisyworld is inhabited solely by black and white daisies. Black daisies live in colder temperatures. Black daisies absorb heat and tend to raise the ambient temperature. White daisies live in warmer temperature. White daisies reflect heat and tend to lower the ambient temperature. Together, the black and white daisies come to a dynamic equilibrium that keeps the planet's temperature within a moderate range.

1. Gaia Theory Background

The Gaia Theory, or Gaia Hypothesis, was developed by Dr. James Lovelock in the mid 1960's while working with Dian Hitchcock on a project for NASA to search for life on Mars [4]. Dr. Lovelock first stated the theory in the journal Atmospheric Environment in 1972 as: "Life regulates the climate and the chemical composition of the atmosphere at an optimum for itself." [2] The theory was further developed in an ongoing collaboration with Lynn Margulis.

The Daisyworld model was developed in collaboration with Andrew Watson as a way to demonstrate the principle of self-regulation [3]. Daisyworld is an imaginary planet populated solely by black and white daisies. Black daisies warm the planet by absorbing heat and white daisies cool it by reflecting heat. As the planet's sun warms up over its lifetime the daisies maintain a temperate climate by altering the balance between black and white. Eventually as the sun gets hot enough no daisy can survive and all life dies out on the planet. The effects beneficial to life on Daisyworld are obtained by means of natural selection only - there is no need for purpose, altruism, teleology or anything beyond normal genetic process [1].

2. Daisyworld Design

Daisyworld is inhabited solely by black and white daisies. The daisies behave as follows:

- black daisies live in temperatures below 25 degrees
  - they absorb heat and raise the ambient temperature by 1 degree per time unit
- white daisies live in temperatures above 15 degrees
  - they reflect heat and lower the ambient temperature by 1 degree per time unit

The daisies in Daisyworld live in Von Neumann neighbourhoods of three cells by three cells. Each cell is occupied by either a black or a white daisy. The current temperature of a cell is calculated as the average temperature of the neighbourhood. After a transport delay, the daisy adjusts its temperature depending on its colour and all the other cells in the neighbourhood are notified. The process is repeated for every cell neighbourhood on the planet. The Daisyworld planet is a ten cell by ten cell rectangle with wrapped borders.

3. Daisyworld Cell-DEVS Implementation

There are two versions of Daisyworld implemented. The original version stores just a temperature in each cell. The second version improves on this by storing both the temperature and the daisy colour encoded as a single number.

3.1. Daisyworld Version 1

To run the Daisyworld v.1 models follow these instructions:

- install the Daisyworld models in a directory inside the directory containing the default DEVS simu.exe and drawlog.exe executables
- run the desired daisyworld*.bat batch file
- open the desired daisyworld*.out output file and view the results (the numbers represent temperature values for each daisy cell, white daisies cannot survive below 15 degrees and black daisies cannot survive above 25 degrees)
- if you use the visualization applet then use the daisyworld.pal palette file

The Daisyworld v.1 model includes following files:

- *daisyworld.bat* - batch file to run the Daisyworld model
- *daisyworld.ma* - Daisyworld model definition
- *daisyworld.val* - initial cell values varying from 5 to 35 for Daisyworld
- *daisyworld.log* - log file obtained by simulating Daisyworld
- *daisyworld.out* - output file obtained by running drawlog on the Daisyworld log file
- *daisyworld.pal* - palette file for all Daisyworld models
- *daisyworld10.bat* - batch file to run the Daisyworld10 model
- *daisyworld10.ma* - Daisyworld10 model definition with an initial temperature of 10 degrees
- *daisyworld10.val* - initial cell values of 10 for Daisyworld10 (redundant)
- *daisyworld10.log* - log file obtained by simulating Daisyworld10
- *daisyworld10.out* - output file obtained by running drawlog on the Disyworld10 log file
- *daisyworld20.bat* - batch file to run the Daisyworld20 model
- *daisyworld20.ma* - Daisyworld20 model definition with an initial temperature of 20 degrees
- *daisyworld20.val* - initial cell values of 20 for Daisyworld20 (redundant)
- *daisyworld20.log* - log file obtained by simulating Daisyworld20
- *daisyworld20.out* - output file obtained by running drawlog on the Disyworld20 log file
- *daisyworld30.bat* -batch file to run the Daisyworld30 model
- *daisyworld30.ma* - Daisyworld30 model definition with an initial temperature of 30 degrees
- *daisyworld30.val* - initial cell values of 30 for Daisyworld30 (redundant)
- *daisyworld30.log* - log file obtained by simulating Daisyworld30
- *daisyworld30.out* - output file obtained by running drawlog on the Disyworld30 log file
- *daisyworld-empty.val* - template file for cell values

3.2. Daisyworld Version 2

Version 2 of the Daisyworld model was improved to explicitly show the daisies' colour as well as their temperature as follows:

- daisy colour is denoted by the integer part of the cell value
  - 0 denotes a black daisy
  - 1 denotes a white daisy
- daisy temperature is denoted by the fractional part of the cell value

- .xxyyy denotes a temperature of xx.yyy degrees

Daisies still live or dies based on the same temperatures described in Section 2.

To run the Daisyworld v.2 models follow these instructions:

- install the Daisyworld models in a directory inside the directory containing the default DEVS simu.exe and drawlog.exe executables
- run the desired daisyworld*.bat batch file
- open the desired daisyworld*.out output file and view the results (the integer parts represent the colour of each daisy cell and the fractional parts represent the temperature of each daisy cell)
- if you use the visualization applet then use the daisyworld.pal palette file

The Daisyworld model includes the following files:

- *daisyworld.bat* - batch file to run the Daisyworld model
- *daisyworld.ma* - Daisyworld model definition
- *daisyworld.val* - initial cell values varying between black and white and temperatures from 5 to 35 for Daisyworld
- *daisyworld.log* - log file obtained by simulating Daisyworld
- *daisyworld.out* - output file obtained by running drawlog on the Daisyworld log file
- *daisyworld.pal* - palette file for all Daisyworld models
- *daisyworldb10.bat* - batch file to run the DaisyworldB10 model
- *daisyworldb10.ma* - DaisyworldB10 model definition with black daisies and an initial temperature of 10 degrees
- *daisyworldb10.log* - log file obtained by simulating DaisyworldB10
- *daisyworldb10.out* - output file obtained by running drawlog on the DisyworldB10 log file
- *daisyworldb20.bat* - batch file to run the DaisyworldB20 model
- *daisyworldb20.ma* - DaisyworldB20 model definition with black daisies and an initial temperature of 20 degrees
- *daisyworldb20.log* - log file obtained by simulating DaisyworldB20
- *daisyworldb20.out* - output file obtained by running drawlog on the DisyworldB20 log file
- *daisyworldb30.bat* - batch file to run the DaisyworldB30 model
- *daisyworldb30.ma* - DaisyworldB30 model definition with black daisies and an initial

temperature of 30 degrees

- *daisyworldb30.log* - log file obtained by simulating DaisyworldB30
- *daisyworldb30.out* - output file obtained by running drawlog on the DisyworldB30 log file
- *daisyworldw10.bat* - batch file to run the DaisyworldW10 model
- *daisyworldw10.ma* - DaisyworldW10 model definition with white daisies and an initial temperature of 10 degrees
- *daisyworldw10.log* - log file obtained by simulating DaisyworldW10
- *daisyworldw10.out* - output file obtained by running drawlog on the DisyworldW10 log file
- *daisyworldw20.bat* - batch file to run the DaisyworldW20 model
- *daisyworldw20.ma* - DaisyworldW20 model definition with white daisies and an initial temperature of 20 degrees
- *daisyworldw20.log* - log file obtained by simulating DaisyworldW20
- *daisyworldw20.out* - output file obtained by running drawlog on the DisyworldW20 log file
- *daisyworldw30.bat* - batch file to run the DaisyworldW30 model
- *daisyworldw30.ma* - DaisyworldW30 model definition with white daisies and an initial temperature of 30 degrees
- *daisyworldw30.log* - log file obtained by simulating DaisyworldW30
- *daisyworldw30.out* - output file obtained by running drawlog on the DisyworldW30 log file
- *daisyworld-empty.val* - template file for cell values

4. Results

The output files for both versions show that the Daisyworld models do self-regulate.

Daisy colour cannot always be known in Daisyworld v.1. When the temperature in a cell is between 15 and 25 degrees the daisy could either be black or white. However if the temperature drops below 15 degrees then the daisy in that cell must be black and if the temperature rises above 25 degrees then the daisy must be white. It is possible to infer the daisy colour for temperatures between 15 and 25 degrees by tracking the colour changes below 15 degrees and above 25 degrees (i.e. if the temperature in a cell drops below 15 degrees then the daisy will be black and it will remain black as long as the temperature does not rise past 25 degrees, conversely if the temperature in a cell rises above 25 degrees then the daisy will be white and it will remain white as

long as the temperature does not drop below 15 degrees).

Daisyworld v.2 does always explicitly indicate the daisy colour as the integer part of the cell value (0 means black, 1 means white). It should be noted that in some instances the colour change does not show up until one delay period after the temperature threshold has been crossed (i.e. it might be possible to still see a white daisy with a temperature below 15 degrees for a single time interval, or to see a black daisy with a temperature above 25 degrees for a single time interval).

5. Future Work

Additional work could be done to damp the effects of temperature changes on daisies. For example changing from the transport delay that is being used currently to an inertial delay would give daisies a grace period before they would die and they would remain alive if the temperature returns to the appropriate range for their colour. It would also be interesting to introduce the concept of seeds, so that if a daisy dies it will be replaced by a germinating seed which would have the chance of being either colour. Another concept that would merit investigating would be to limit the daisies' lifespan so they eventually grow old an die even if the temperature does not go outside their preferred range. Otherwise, it might also be possible to allow daisies to show a greater amount of colour variation, thus introducing grey daisies or daisies that can be a variety of shades of grey.

References

[1] N. Charlton, "James Lovelock and the Gaia Theory", http://www.lancs.ac.uk/users/philosophy/mave/guide/gaiath~1.htm

[2] J. Lovelock, "The Evolving Gaia Theory", United Nations University, Sept. 25, 1992, http://www.unu.edu/unupress/lecture1.html

[3] D. Orrel, "Gaia Theory: Science of the Living Earth", http://www.gaianet.fsbusiness.co.uk/gaiatheory.html

[4] "The Gaia Hypothesis", http://www.kheper.auz.com/gaia/Gaia_Hypothesis.htm