BRNO UNIVERSITY OF TECHNOLOGY

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FACULTY OF INFORMATION TECHNOLOGY

Modelling and Simulation

Theme 4: Breeding of insects for food and industrial purposes

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December 9, 2018

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1 Introduction

This project was made to simulate model of ladybird farm and ways of getting income from the farm. Using the model and experiments reader will get notion of how different aspects of farm change under certain circumstances. General purpose of the project is to demonstrate (un-)profitability of ladybird farm in environment of Czechia.

1.1 Authors and information sources

Autors of the project are Ivan Manoilov and Farrukh Abdukhalikov. While developing the model and project knowledge gained from articles[1][2][3]. For exact model developing following knowledges were essential: ladybird lifecycle, nutrition of ladybird, ability of ladybirds to eradicate aphids from farmlands.

1.2 Model validation

Validation of model was made through experiments, however because of unwide spread of ladybird farms and whole unpopularity of the theme some facts were hard to prove right. Because of that, some data might be not exact and gained from deduction rather than statistically.

2 Analysis of theme and used methods/technologies

For modelling and simulation of farm we need to know real aspects of industry and ladybirds lifecycle. Ladybirds are generally used for eradication of aphids in farmlands. Also ladybirds can be sold to other farmers, who intend to have a BIO farm.
We've chosen both of the ways to gain profit from ladybirds as a model. 72,000 of ladybirds are known to eradicate around of 1 acre ($\approx$ 0.4 ha) [1]. Pesticide coverage of 1 acre costs farmers around of 66$[4], while initial acquisition of equivalent ladybird beetles would cost around of 99$[5].
In case of farmer planning to raise his own population of ladybirds additional costs are needed. Food needed for ladybirds larvas in 4 instars of their life can vary from 35 to 300 [2] aphids. Time needed for ladybird to develop into an adult can vary from 16 to 21 day[2][3]. Another precise numbers for given instars are in the table 1:

Field	Value	Source
Duration of egg stage	2-3 days	Article[2][3]
Duration of larva stage	1-2 days	Article[2][3]
Duration of 2nd instar stage	2-4 days	Article[2][3]
Duration of 3rd instar stage	2-4 days	Article[2][3]
Duration of 4th instar stage	2-4 days	Article[2][3]
Duration of pupal stage	5-8 days	Article[2][3]
Amount of aphids consumed during larva stage	35	Article[2][3]
Amount of aphids consumed during 2nd instar stage	65	Article[2][3]
Amount of aphids consumed during 3rd instar stage	96	Article[2][3]
Amount of aphids consumed during 4th instar stage	296	Article[2][3]

Table 1: Model data and sources

2.1 Used technologies

We've modelled our systems as a set of objects and interaction between them, so in given set of languages, we've chosen C++. For simulation purposes SIMLIB[6] library was used, as it's written perfectly for purposes of the project. Used constructions and algorithms can be found in slides to IMS [7] (162-208) and first[8] and second[9] exercises.

3 Conception - modelling points

Target of the project is to simulate ([7] ,slide 8) activity and economical point of view of ladybird farm.
Simulation doesn't require model of whole farm (simulation of driving live ladybirds to market, simulation of farmer activity), but life cycle of ladybird and respective amounts of eaten food(aphids) for each phase of life cycle.

Several fields were skipped as unecessary: gender division of ladybugs. It is usually 1:1 [2][3] and generally irrelevant, except the fact, that only female ladybirds lay eggs, which was described as a 50% chance to lay eggs for every ladybird.

3.1 Design of conceptual model

Entry point of simulation is current amount of living ladybirds, which is generated accordingly to parameter of simulation. Ladybird will go through whole life cycle in the simulation, untill it'll finally leave it either by being sold or by passing away.
Output of the system([7],slide 7) is a collection of values - amount of ladybirds farmer currently has, amount of money farmer has either saved or gained.

3.2 Forms of conceptual model

Abstract model of ladybird farm was described by Perti net ([7],slide 123) on basis of gained knowledges written above. Picture of Petri net is shown in additional files name **petriNet.png**.

4 Architecture of simulation model/simulator

Implementation is based on class `Generator`, which inherits class `Event`([7], slide 169). This class generates initial amount of ladybirds needed to start the simulation. It generates exact amount of ladybirds, which was entered by user as an argument to the program. The amount represents one thousand of ladybirds. This abstraction was made because of limitations of SIMLIB engine (according to our model processing of 1000 tokens would take days of real time).
Ladybird is implemented via class `LadyBird` which inherits class `Process`([7], slide 171). It simulates ladybird life cycle via entering and leaving different instances of class `Store`([7], slide 184) contained in class `Farm`. `Farm` is a wrapper for simulation model, it contains all instances of `Store` and current amount of ladybirds as well as given amount of acres, which farmer possesses. Some transitions (especially ones describing phases of development of ladybird) between different `Stores` are controlled with `Exponential`([7], slide 167). Workaround with ladybird genders mentioned above (section 3, last line) is realized via `Random`([7], slide 98) and comparison (e.g. if event should occur with probability of 30% we should compare output of `Random` with 0.3).

5 The essence of simulation experiments and their course

Because of uncertainty and unclear origin of some facts our first goal was to determine right parameters to our application, so it will function as real world system. So first experiments were targeted on the correction of arguments,making experiments more effecient through changing source code therefore they won't be stated here.

5.1 General course of experiments

General course of experiments can be describe in steps below:

1. Gaining arguments, that need more analysis and inspection
2. Running simulation with those arguments
3. Comparison of output of system with expected output or real world model

5.2 Experiments

5.2.1 First experiment

First experiment essence is in farmer having no land to protect from aphids, so all the ladybirds will be sold. Input parameters were: 0 for acres farmer owns, 10 for amount of ladybirds thousands farmer initially buys, 10 for amount of days we'll wait till end of simulation. Results are listed below in table 2:

Current amount of lady birds	0
Net profit	-11$

Table 2: First experiment results

5.2.2 Second experiment

Second experiment lays in farmer keeping all ladybirds to himself, therefore saving money on pesticides, but not gaining money from sells of ladybirds. Input parameters were: 100 for amount of acres of land, 10 for amount of ladybirds thousands farmer initially buys, 10 for amount of days. Results are listed below in table 3:

Current amount of lady birds	50
Net profit	324$

Table 3: Second experiment results

5.2.3 Third experiment

Third experiment lays in perfect balance between farmland size and amount of ladybirds. Farmer will always have enough thousands of ladybirds to protect his farmlands and save 66$ on pesticides for each acre, but farmer will sell extra ladybirds, he currently doesn't need. This will result in increasing profit. Input parameters were: 5 for amount of acres of land, 20 for amount of ladybirds thousands farmer initially buys, 75 for amount of days. Results are listed below in table 4:

Current amount of lady birds	37
Net profit	3189.7$

Table 4: Third experiment results

5.3 Experiment conclusion

16 tests were held, only three extraordinary and meaningful were shown above. First test may say us that model is wrong, but after short debates, we came to conclusion, that farmer, which has no lands for ladybirds to live/mate/feed on, should sell them immediately at lowered price. Our conclusion was shown in results. Generally experiments showed us, that a perfect balance in amount of ladybirds and acres is almost impossible to find, but can be approximated with our simulation and system.
All tests will be run and results will be shown on screen by entering `make run`.

6 Summary of simulation experiments and conclusion

Our system proves itself as acceptably close to real world example. Majority of the flaws is caused by inaccuracy of data found or nonexistence of the data in open Internet. The model is able to simulate ladybird farm and help starting farmers to approximate better conditions for their farm.

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