

Department of Systems and Computer Engineering

SYSC 5104 - Methodologies for Discrete Event Modelling and Simulation

Dynamics of Lynx-Hare System using Cell DEVS

Assignment 2

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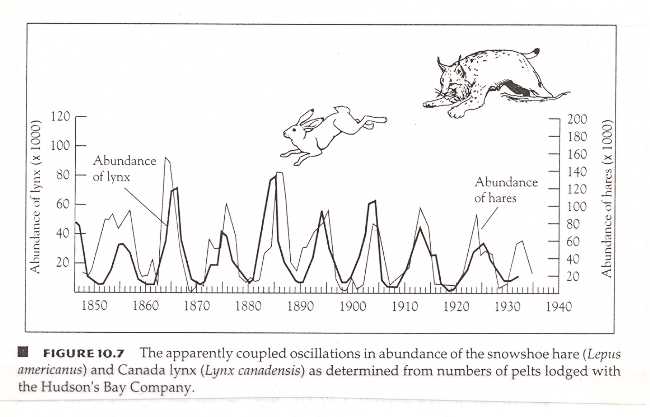
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Part 1

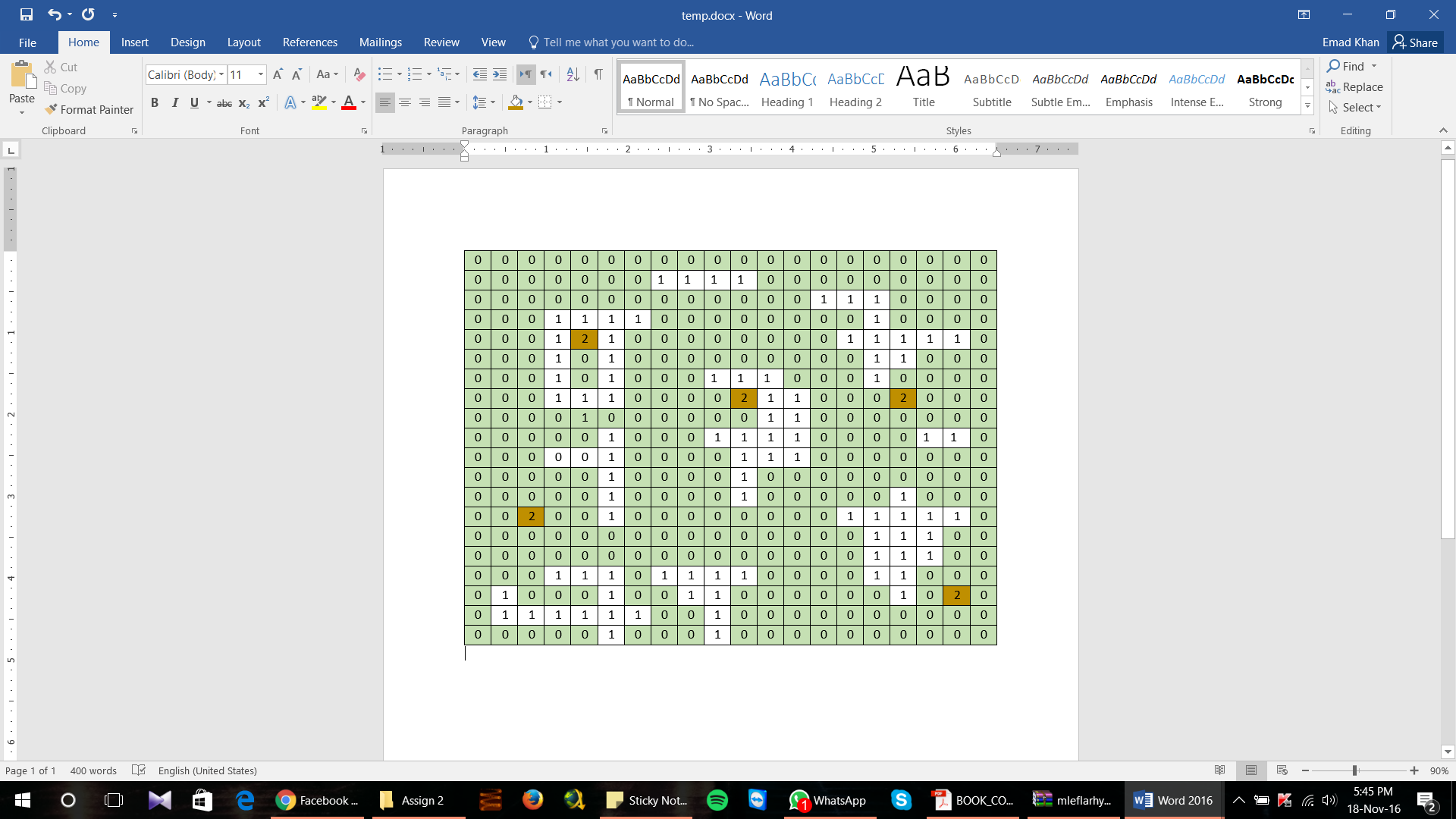
# **Conceptual Model**

The goal is to build a predator-prey model which examines the bevaiour of hares and lynxes. Both populations do not exist independently from one another, because lynxes feed basically from hares. The model will simulate hares and lynx with population data extracted from the Hudson’s Bay Company’s study on the hare-lynx system. It will also apply rules studied in the research paper by L. V. Nedorezov on The Dynamics of the Lynx–Hare System: An Application of the Lotka–Volterra Model. Using these dynamic, I will model them via cellular automata.



The initial number of lynx and hares are randomly distributed in a rectangular grid of 20 x 20. The cells states in the grid are updated according to the local dynamics rules of each cell. For instance, 100 hares and 10 lynxes are placed at random positions. All hares and lynxes have a reproductive age which will be set during the design of the model.

The predator-prey modelling cellular automata is shown bellows. The ground is represented by a value of zero ‘0’. A hare is represented with a value of ‘1’ and a lynx is shown with a value of ‘2’. The first image shows at initiation and the second image shows what it is expected to look like after a few seconds of simulation.



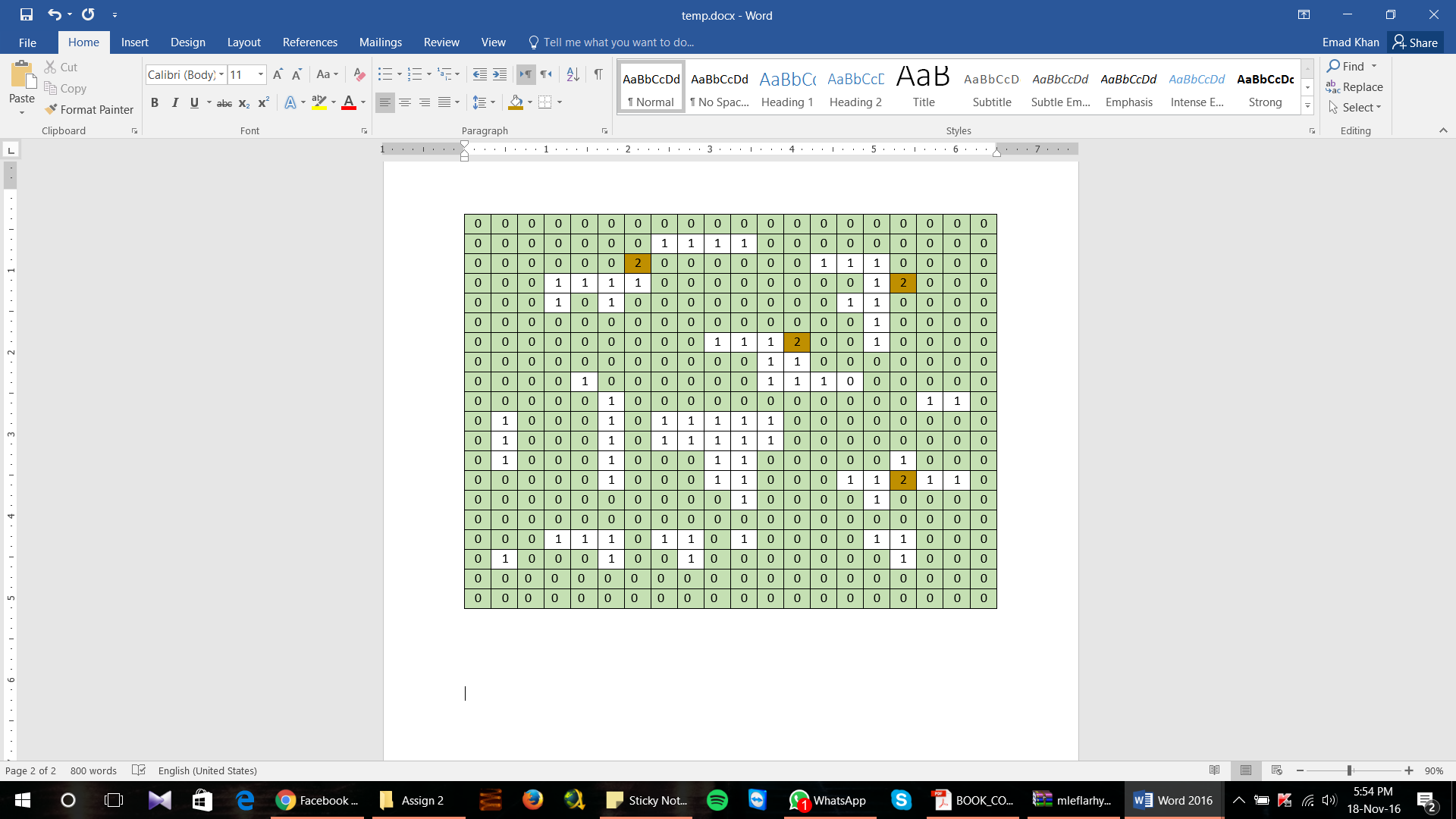


Fig 2: After seconds of simulation

Fig 1: At initial condition

We can see that it can be represented using the Cell DEVS formalism and Cellular Automata can be used to emulate the behavior of the lynx-hare system. Figure 2 shows the population of hares and lynx reduced and scattered based on the rules we would set.

Some of the rules that the model will consider will be that each cell in the grid could represents three things; lynx, hare or just snow ground. The hare’s movement will be random whereas the lynx will follow an energy pattern. If the lynx doesn’t receive enough energy after several movements, it will die. When the lynx eats a hare, it gains energy and goes on searching for more. The lynxes reproduce after sometime once it has gained energy. The hares also reproduce after a limited amount of time. The movements of lynxes will be described during the simulation.

Part 2

**Rules for Lynx Hare System**

The rules below define the growth of hares and lynxes. For this system I have assumed only certain growth rules. Here if a cell has 3 or 4 adjacent neighboring cells of the same kind (i.e. lynxes or hares) it will reproduce to the cell of the same kind. So for example if there is a hare in the East, North and West neighboring cell of a hare, it will produce a hares.

%Growth Rules

%For Hares

rule : 1 100 { (0,0) = 1 and (-1,0) != 0 and (0,1) != 0 and (1,0) != 0 and (0,-1) != 0 }

rule : 1 100 { (0,0) = 1 and (0,-1) = 1 and (-1,0) = 1 and (0,1) = 1 }

rule : 1 100 { (0,0) = 1 and (-1,0) = 1 and (0,1) = 1 and (1,0) = 1}

rule : 1 100 { (0,0) = 1 and (0,1) = 1 and (1,0) = 1 and (0,-1) = 1 }

rule : 1 100 { (0,0) = 1 and (1,0) = 1 and (0,-1) = 1 and (-1,0) = 1 }

%For Lynxes

rule : 2 70 { (0,0) = 2 and (-1,0) = 2 and (0,1) = 2 and (1,0) = 2 and (0,-1) = 2 }

rule : 2 70 { (0,0) = 2 and (0,-1) = 2 and (-1,0) = 2 }

rule : 2 70 { (0,0) = 2 and (0,1) = 2 and (-1,0) = 2 }

rule : 2 70 { (0,0) = 2 and (0,1) = 2 and (1,0) = 2 }

rule : 2 70 { (0,0) = 2 and (0,-1) = 2 and (1,0) = 2 }

**DEVS Formalism**

The Atomic Cell DEVS Model is described as:

*is the set of input external events*

*is the set of output external events*

*is the state set;*

*Here 0 represents ground, 1 is hare and 2 is lynx*

*is the set of input values*

{ (-2,0), (-1,-1), (-1,0), (-1,1), (0,-2), (0,-1), (0,0), (0,1), (0,2), (1,-1), (1,0), (1,1), (2,0) }

*is the kind of delay (transport/inertial/other);*

= Inertial

*is the delay for the cell*

: These rules can be found in the lynxhare.ma file

Growth Rules

%Growth Rules

%For Hares

rule : 1 100 { (0,0) = 1 and (-1,0) != 0 and (0,1) != 0 and (1,0) != 0 and (0,-1) != 0 }

rule : 1 100 { (0,0) = 1 and (0,-1) = 1 and (-1,0) = 1 and (0,1) = 1 }

rule : 1 100 { (0,0) = 1 and (-1,0) = 1 and (0,1) = 1 and (1,0) = 1}

rule : 1 100 { (0,0) = 1 and (0,1) = 1 and (1,0) = 1 and (0,-1) = 1 }

rule : 1 100 { (0,0) = 1 and (1,0) = 1 and (0,-1) = 1 and (-1,0) = 1 }

%For Lynxes

rule : 2 70 { (0,0) = 2 and (-1,0) = 2 and (0,1) = 2 and (1,0) = 2 and (0,-1) = 2 }

rule : 2 70 { (0,0) = 2 and (0,-1) = 2 and (-1,0) = 2 }

rule : 2 70 { (0,0) = 2 and (0,1) = 2 and (-1,0) = 2 }

rule : 2 70 { (0,0) = 2 and (0,1) = 2 and (1,0) = 2 }

rule : 2 70 { (0,0) = 2 and (0,-1) = 2 and (1,0) = 2 }

%Lynx Rules

rule : 0 70 { (0,0) = 2 and (-1,0) = 1 }

rule : 0 70 { (0,0) = 2 and (0,1) = 1 }

rule : 0 70 { (0,0) = 2 and (1,0) = 1 }

rule : 0 70 { (0,0) = 2 and (0,-1) = 1 }

rule : 2 70 { (0,0) = 1 and (1,0) = 2 }

rule : 2 70 { (0,0) = 1 and (0,-1) = 2 and (-1,-1) = 0}

rule : 2 70 { (0,0) = 1 and (-1,0) = 2 and ((-2,0) = 0 and (-1,1) = 0) }

rule : 2 70 { (0,0) = 1 and (0,1) = 2 and ((0,2) = 0 and (-1,1) = 0 and (1,1) = 0 )}

rule : 0 100 { (0,0) = 1 and ((0,1) = 0 or (1,0) = 0 or (0,-1) = 0 or (-1,0) = 0 )}

%Hare Movement Rules

rule : 1 100 { (0,0) = 0 and (1,0) = 1 }

rule : 1 100 { (0,0) = 0 and ((0,-1) = 1 and (-1,-1) = 1)}

rule : 1 100 { (0,0) = 0 and ((-1,0) = 1 and (-2,0) = 1 and (-1,1) = 1) }

rule : 1 100 { (0,0) = 0 and ((0,1) = 1 and (-1,1) = 1 and (0,2) = 1 and (1,1) = 1)}

rule : 2 70 { (0,0) = 0 and (1,0) = 2 and (1,1) != 1 and (2,0) != 1 and (1,-1) != 1}

rule : 2 70 { (0,0) = 0 and ((0,-1) = 2 and (-1,-1) = 2)}

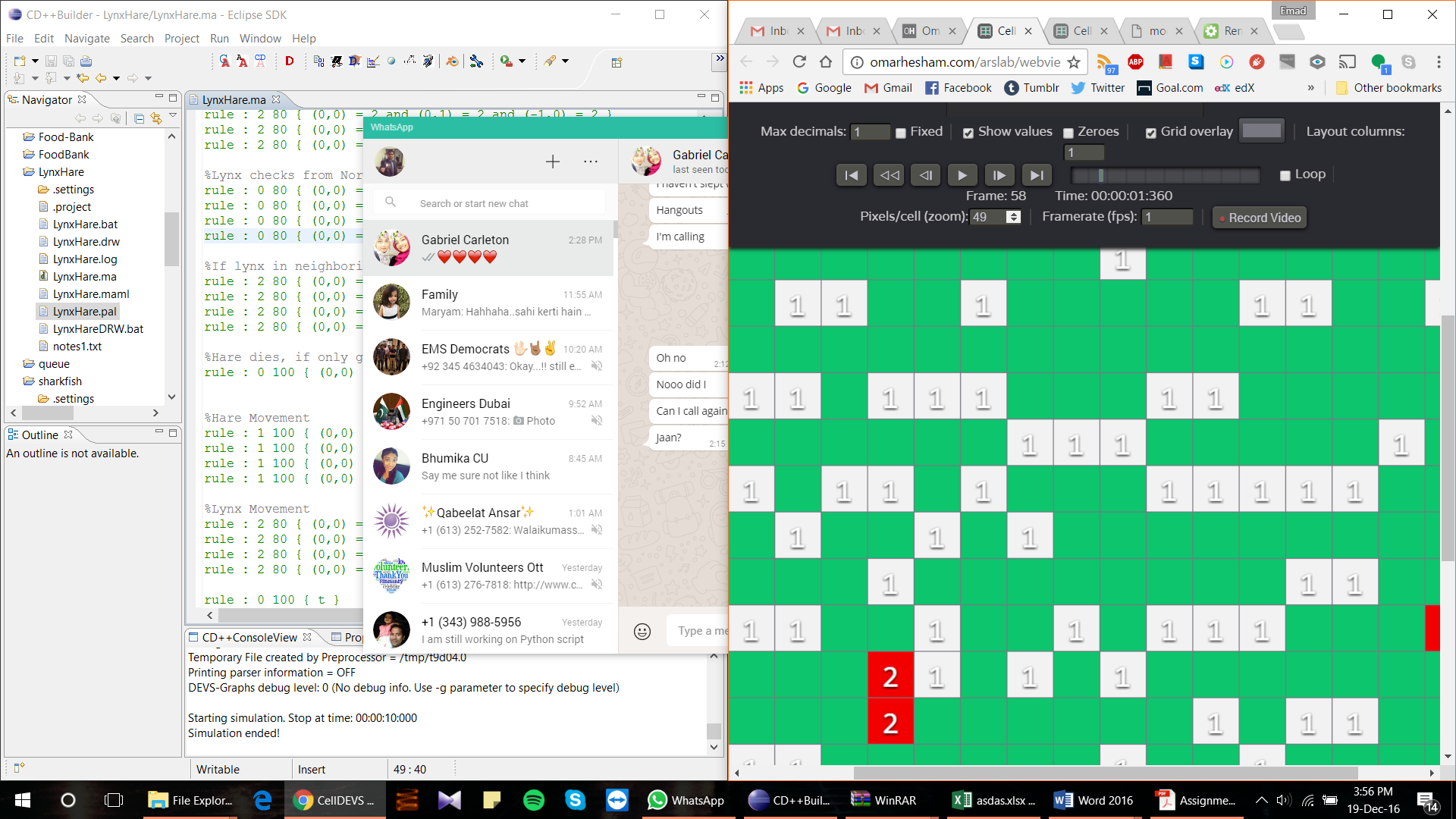
rule : 2 70 { (0,0) = 0 and ((-1,0) = 2 and (-2,0) = 2 and (-1,1) = 2) }

rule : 2 70 { (0,0) = 0 and ((0,1) = 2 and (-1,1) = 2 and (0,2) = 2 and (1,1) = 2)}

*Here, I have kept hare transitions at 100 msec and lynx transitions at 70 msec. This is because I want the delay in lynx to be slower so lynxes can catch hares. Otherwise if the delay is same, it takes longer to catch hares and for the lynxes to grow.*

**Simulation and Testing**

The model was first run with only hares. A problem aroused and it was due to collision of cells. For example, as shown below, if 1 represents the hares, and the growth rule makes the green cell in between turn to 1, there appears a collision, and the neighboring cells are lost.



Similar behavior is observed when lynxes are added. The simulation should run with lynxes preying on the hares, but it is seen that there are cases that lynxes are lost due to collisions. Besides this problem, the model simulates the expected results.

After defining and compiling the rules for the simulation, the following results were obtained:

initialvalue : 0

initialrowvalue : 1 00111011100011100200

initialrowvalue : 2 01001001010100100100

initialrowvalue : 3 10100110100011111010

initialrowvalue : 4 00111120100120110010

initialrowvalue : 5 10111010201011100110

initialrowvalue : 7 01011001111100100100

initialrowvalue : 8 00111110101011011011

initialrowvalue : 9 00001100100110112010

initialrowvalue : 10 00111001100011120110

initialrowvalue : 11 01001001010100100100

initialrowvalue : 12 10111110100011111010

initialrowvalue : 14 00201100100000110010

initialrowvalue : 16 00111011100011120000

initialrowvalue : 17 01001001111100100100

initialrowvalue : 18 00111110100011111010

initialrowvalue : 19 00001100100000110210

In this simulation, ground is represented by a green cell and has value 0. Hares are white cell and have a value 1, whereas lynxes are red and value of 2.

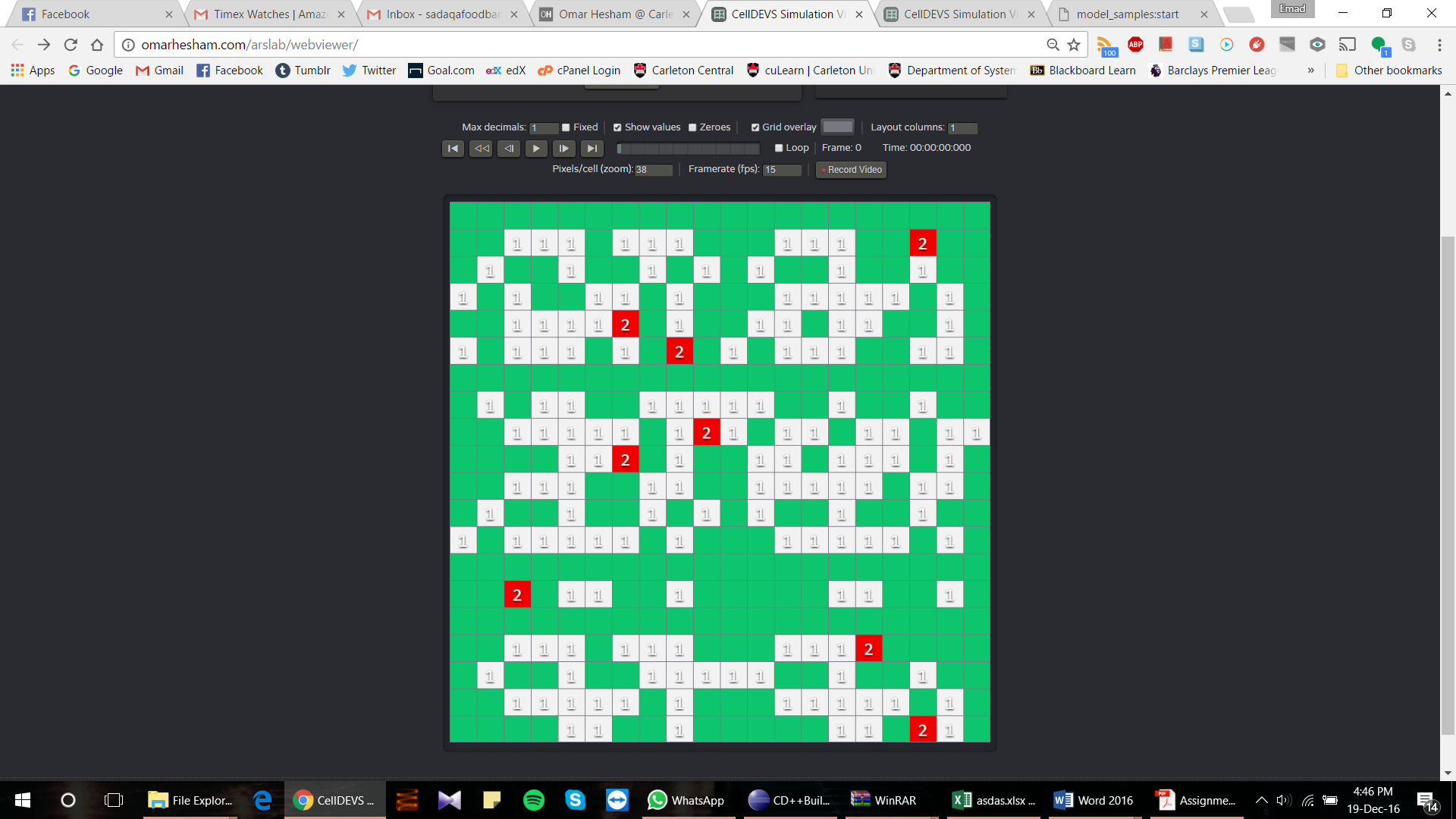


Fig 1. Initial state

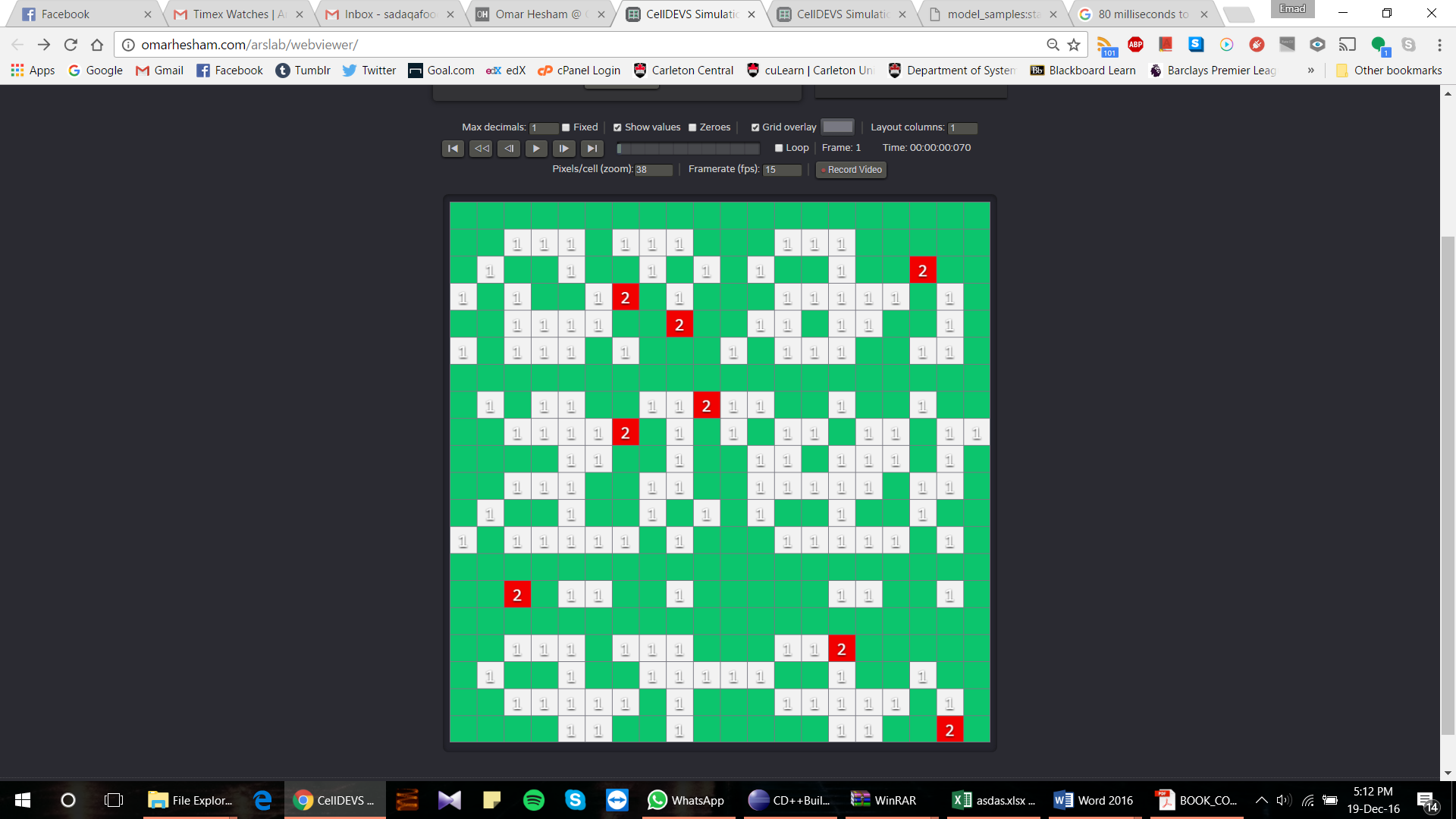


Fig 2. After 70 msec

After 70 msec, the lynxes move to the hare cells according to the rules defined.

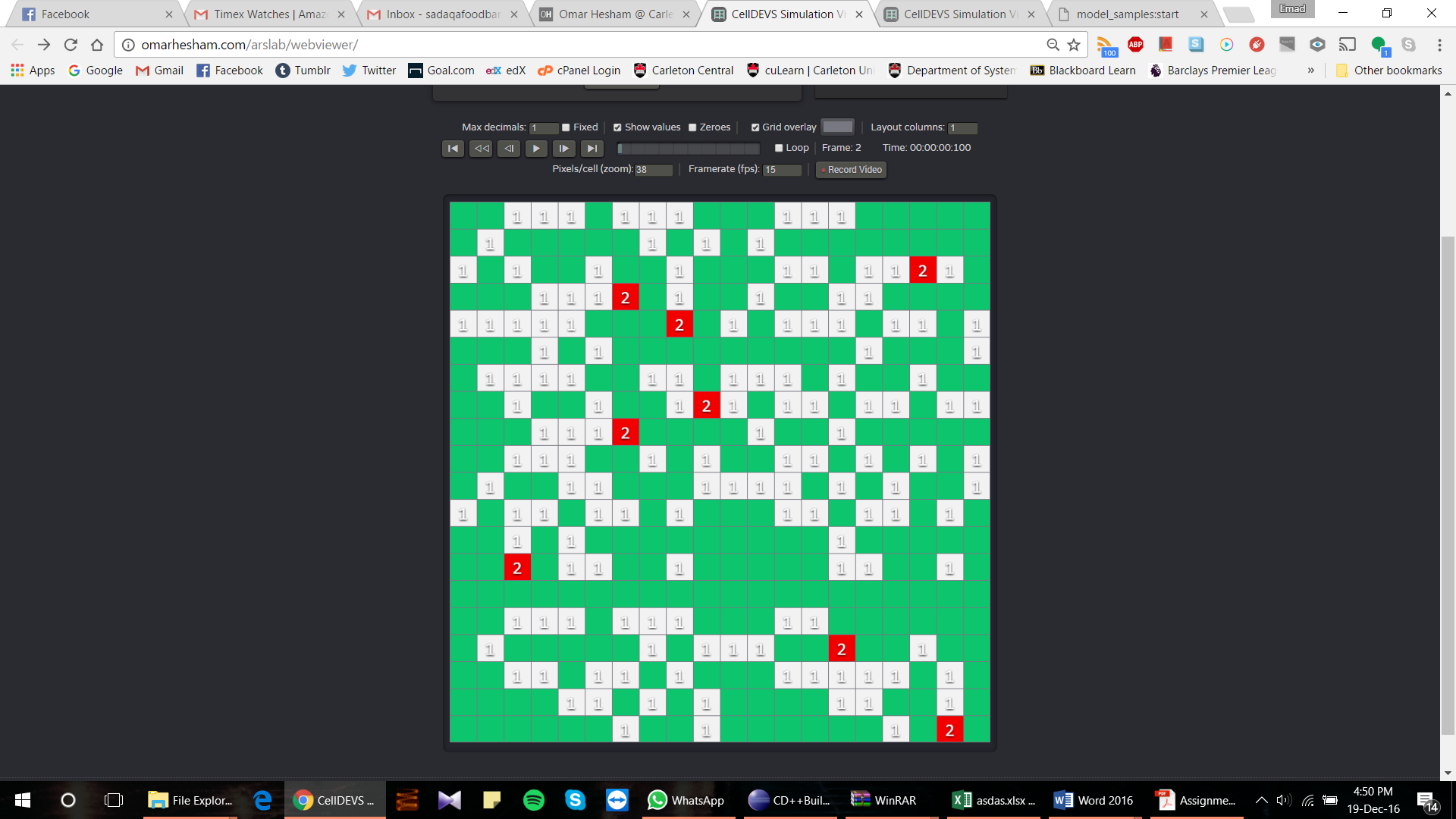


Fig 3. After 100 msec

After 100 msec, the hares move to the next cells according to the rules defined.



Fig 4. After 140 msec

After 140 msec, (0.7 + 0.7) the lynxes move once again towards hares.

This cycle follows and the simulation completes. Some lynxes are lost due to collisions.

**References:**

[1] L. V. Nedorezov, *The Dynamics of the Lynx–Hare System: An Application of the Lotka–Volterra Model*, Research Center for Interdisciplinary Environmental Cooperation, Russian Academy of Sciences,

nab. Kutuzova 14, St. Petersburg, 191187 Russia

[2] Mario Martinez-Molina, Marco A. Moreno-Armendariz, Nareli Cruz-Cortes, and Juan Carlos Seck Tuoh Mora (2011), ‘*Modeling Prey-Predator Dynamics via Particle Swarm Optimization and Cellular Automata’*, Advances in Soft Computing, 10th Mexican International Conference on Artificial Intelligence, MICAI 2011, Puebla, Mexico, Proceedings, Part II

[3] Joseph M. Mahaffy, *Lotka-Volterra Models*, Math 636 - Mathematical Modeling Fall Semester, 2010. Link: <http://jmahaffy.sdsu.edu/courses/f09/math636/lectures/lotka/qualde2.html#ref>