

**3Models Framework: An application to
support evolution of computational
biological models**

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June 21 2006

version 1.0

Contents

1. PROGRAM OVERVIEW	3
2. WALKTHROUGH	4
2.1. INTERFACE	4
2.2. RUNNING A SIMULATION	5
2.2.1. <i>Create an AG model</i>	5
2.2.2. <i>Creating the network model</i>	6
2.2.3. <i>Creating the lineage tree model</i>	8
2.3. RUNNING ADDITIONAL SIMULATIONS	14
3. CREDITS.....	15

1. Program Overview

The 3Models framework allows an artificial genome (AG) model to be mapped (or transformed) onto a network which can then be mapped onto a lineage tree, and subsequently, evolved over time. Changes can therefore be traced at each level originating from the AG level. In this framework, the AG model is based on Reil's work and the network model is based on a random boolean network. The framework comes with an application called 3Models.jar. The main class of the application resides in *FrameworkApplication.java* and is part of the 3modelsframework.application package. This manual talks about this particular application and how it works. An assumption of biological models is required. The application is a simple prototype which can be used as a reference to develop a more visually pleasing application. Because it is only a prototype, there may be minor issues when incorrect input is provided however this should not be a cause for concern. This application requires that Java 1.4.2 or above to be installed within the system.

2. Walkthrough

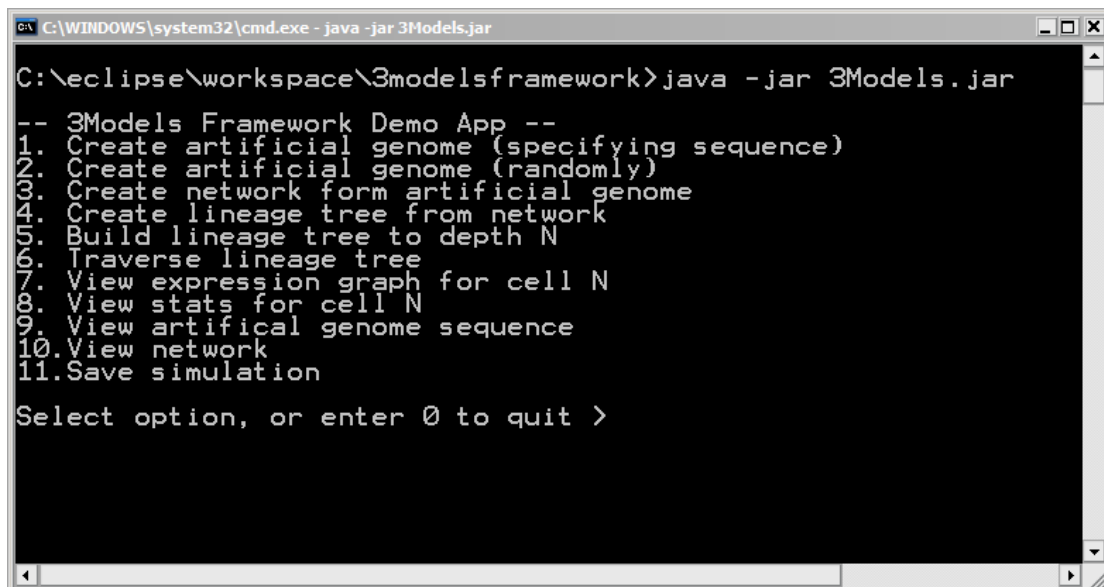
This section provides a quick walkthrough of the application. After following this walkthrough, you will be familiar with how the application works.

2.1. Interface

The application is a simple command line based interface. To run the application simply type

```
java -jar 3Models.jar
```

The following menu should appear upon execution.



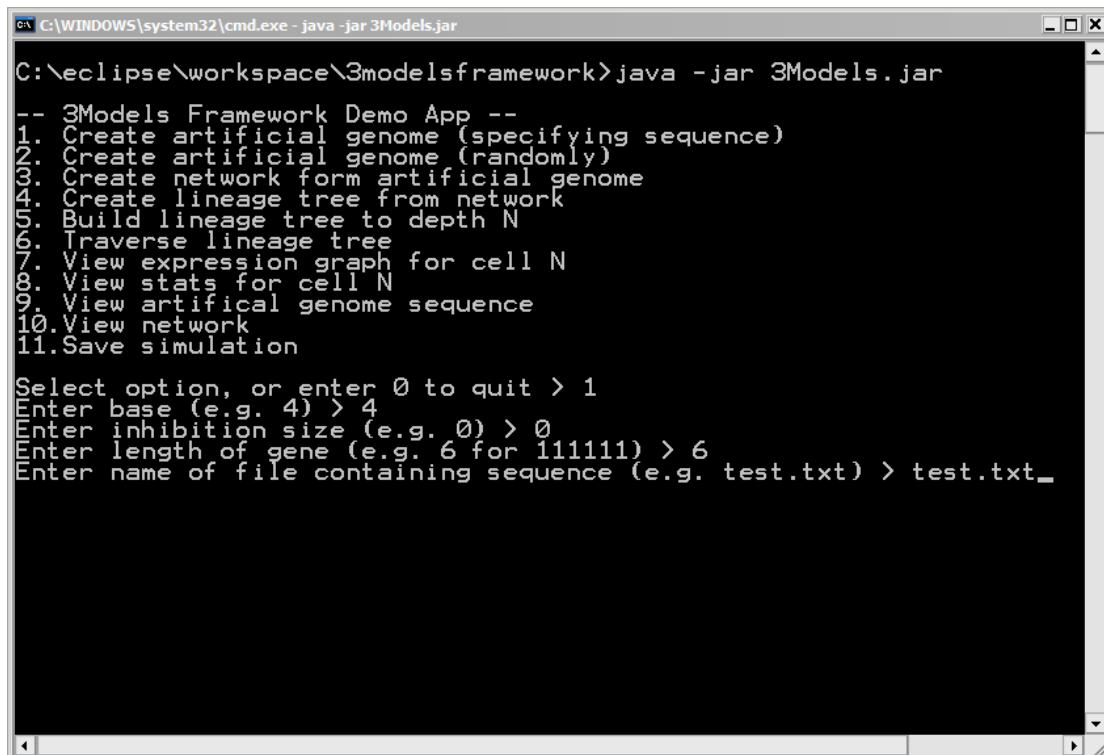
```
C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar
C:\eclipse\workspace\3modelsframework>java -jar 3Models.jar
-- 3Models Framework Demo App --
1. Create artificial genome (specifying sequence)
2. Create artificial genome (randomly)
3. Create network form artificial genome
4. Create lineage tree from network
5. Build lineage tree to depth N
6. Traverse lineage tree
7. View expression graph for cell N
8. View stats for cell N
9. View artificial genome sequence
10. View network
11. Save simulation
Select option, or enter 0 to quit >
```

You can see that there are 11 menu options available, most of which are self explanatory. The next section will explore these options in further depth.

2.2. Running a simulation

To start a simulation, select option 1 or 2 from the menu first. For this walkthrough, the sequence will be specified. This sequence can be found in the same directory as the application in a file named *test.txt*. The next screenshot shows option 1 being selected. In the software, an artificial genome must be created first, followed by the network model, and then the lineage tree model

2.2.1. Create an AG model



```
C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar
C:\eclipse\workspace\3modelsframework>java -jar 3Models.jar
-- 3Models Framework Demo App --
1. Create artificial genome (specifying sequence)
2. Create artificial genome (randomly)
3. Create network form artificial genome
4. Create lineage tree from network
5. Build lineage tree to depth N
6. Traverse lineage tree
7. View expression graph for cell N
8. View stats for cell N
9. View artificial genome sequence
10. View network
11. Save simulation
Select option, or enter 0 to quit > 1
Enter base (e.g. 4) > 4
Enter inhibition size (e.g. 0) > 0
Enter length of gene (e.g. 6 for 111111) > 6
Enter name of file containing sequence (e.g. test.txt) > test.txt_
```

The AG base that is used is a set of digits from 0 to 3, so a base of 4. The network that we are creating has no inhibitions, so we set this to 0. If we use a value of 1, a random number will be picked between 0 and 3 and if the last digit of the gene contains this number, then the gene will be inhibited. Likewise if we use a value of 2, then 2 random numbers will be used. The random seed for a specified sequence is fixed at 0, however if you want a random sequence to be generated, this seed can be specified. The final option is to specify the length of the gene, in our sequence we want this to be a length of 6. Finally we specify the name of the file which contains the sequence. This file contains the sequence that we want to load in our simulation.

Upon hitting the enter key, the sequence is loaded and the AG model created. This is shown in the next screen.

```

C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar
Enter name of file containing sequence (e.g. test.txt)
AG Model created!

-- 3Models Framework Demo App --
1. Create artificial genome (specifying sequence)
2. Create artificial genome (randomly)
3. Create network form artificial genome
4. Create lineage tree from network
5. Build lineage tree to depth N
6. Traverse lineage tree
7. View expression graph for cell N
8. View stats for cell N
9. View artificial genome sequence
10. View network
11. Save simulation

Select option, or enter 0 to quit > 9

```

The creation of the AG model can be verified by selecting option 9. Part of the sequence is shown in the next screen.

```

C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar
1123322231133102100220310020023131310003120101233122002
1323320133123203000002311033133033230101231331101202131
3301320320202021232212030031302001200013120211222301111
1000320132213311213311123111000013302020113221200131111
031012323212020312111101331233332310033302330133011120
2101323100330020031101210320030032130000220103101010310
2303123313021331133232330322000101130201033100222221031
0020013100322202231330022202210223010303211033110232003
1300331203012233023301221023012331203221032000221210230
3212310221212303230112133020032303111123003012000001012
0012101021012211022001211321213000221112310200012232120
222033213100101010122022210331212322111230133021013021
3001101312321010310231132121222012231103100033031001222
2200110013021330022001112100330220302120121211220103311
022323022212012100201232001023222210233131022332230010
3322110112300003310120022133101112120322233233030301321
3132131201231130130103011130133031203203020311330322310
022323202130112102221333312332113103313

```

Once the AG model has been created, the next step would be to create the network model from the AG model. This is discussed in the next section.

2.2.2. Creating the network model

The AG model must be created first prior to creation of the network model. The network model is created by selecting option 3 from the menu. This is shown in the next screen.

```

C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar
22001100130213300220011121003302203021201212112201033113203
02232302221201210020123200102322222102331310223322300102132
33221101123000033101200221331011121203222332330303013212123
31321312012311301301030111301330312032030203113303223102133
022323202130112102221333312332113103313

-- 3Models Framework Demo App --
1. Create artificial genome (specifying sequence)
2. Create artificial genome (randomly)
3. Create network form artificial genome
4. Create lineage tree from network
5. Build lineage tree to depth N
6. Traverse lineage tree
7. View expression graph for cell N
8. View stats for cell N
9. View artifiical genome sequence
10. View network
11. Save simulation

Select option, or enter 0 to quit > 3
Enter timesteps to allocate for the network (e.g. 10) > 10

```

Timesteps has to be allocated for the network in order for the gene expression graph to be created. For our AG model, a timestep of 10 is more than enough. This number is up to you to decide.

Once the timesteps parameter is entered, the network is created. For the particular AG model, 18 nodes were created and there is an average connectivity of 0.78 for each node.

```

C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar
9. View artifiical genome sequence
10. View network
11. Save simulation

Select option, or enter 0 to quit > 3
Enter timesteps to allocate for the network (e.g. 10) > 10
Network Model created!
There are 18 nodes
K (Average connectivity per node) is 0.7777777777777778

-- 3Models Framework Demo App --
1. Create artificial genome (specifying sequence)
2. Create artificial genome (randomly)
3. Create network form artificial genome
4. Create lineage tree from network
5. Build lineage tree to depth N
6. Traverse lineage tree
7. View expression graph for cell N
8. View stats for cell N
9. View artifiical genome sequence
10. View network
11. Save simulation

Select option, or enter 0 to quit > 10

```

The network can be viewed by selecting option 10. The results are shown in the in the next screen.

```

C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar
9. View artificial genome sequence
10. View network
11. Save simulation

Select option, or enter 0 to quit > 10
Gene 223231 18
Gene 101323 19 -> 28:T 30:T
Gene 131222 20
Gene 222133 21 -> 27:T
Gene 031213 22 -> 27:T 33:T
Gene 300132 23 -> 25:T
Gene 012210 24 -> 18:T 27:T
Gene 032012 25
Gene 312000 26 -> 29:T
Gene 231230 27
Gene 233122 28 -> 25:T
Gene 231331 29
Gene 031031 30 -> 27:T 28:T
Gene 011223 31 -> 34:T
Gene 130201 32
Gene 101312 33 -> 25:T
Gene 230032 34
Gene 010122 35

```

The full listing of the 18 network nodes is shown here. The output is described as follows. Gene “223231” has an id of 18, and does not regulate any other genes. Gene “101323” has an id of 19, and regulates (i.e. the -> arrow) the gene with id 28 (which is gene “233122”) and the gene with id 30 (which is gene “031031”). The links from gene 19 regulating genes with id 28 and 30 are set to a status of true, which means they are active and not inhibited (remember earlier that we specified inhibition to be 0). If this was changed to “28:F 30:F”, it would mean that the links are inhibitory links. This same explanation applies to the rest of the genes. Altogether from the above, there are 4 genes which regulate 2 genes each, 6 genes which regulate 1 gene each, and the 8 genes which do not regulate other genes.

The lineage tree can now be constructed. This is discussed in the next section.

2.2.3. Creating the lineage tree model

The network model must be created first prior to creation of the lineage tree model. The network model is created by selecting option 4 from the menu. This is shown in the next screen.

```

C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar
Gene 231230 27
Gene 233122 28 -> 25:T
Gene 231331 29
Gene 031031 30 -> 27:T 28:T
Gene 011223 31 -> 34:T
Gene 130201 32
Gene 101312 33 -> 25:T
Gene 230032 34
Gene 010122 35

-- 3Models Framework Demo App --
1. Create artificial genome (specifying sequence)
2. Create artificial genome (randomly)
3. Create network form artificial genome
4. Create lineage tree from network
5. Build lineage tree to depth N
6. Traverse lineage tree
7. View expression graph for cell N
8. View stats for cell N
9. View artificial genome sequence
10. View network
11. Save simulation

Select option, or enter 0 to quit > 4

```


Once the enter key is pressed, the following screen will appear.

```

C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar
7. View expression graph for cell N
8. View stats for cell N
9. View artificial genome sequence
10. View network
11. Save simulation
Select option, or enter 0 to quit > 4
List of genes
0. 223231
1. 101323
2. 131222
3. 222133
4. 031213
5. 300132
6. 012210
7. 032012
8. 312000
9. 231230
10. 233122
11. 231331
12. 031031
13. 011223
14. 130201
15. 101312
16. 230032
17. 010122
Enter the gene id you wish to make as left input (e.g. 0) > 1
Enter the gene id you wish to make as right input (e.g. 1) > 6
Enter the gene id you wish to make as division output node (e.g. 2) > 10
Enter the gene id you wish to make as differentiate output node (e.g. 3) > 0
Enter the gene id you wish to make as death output node (e.g. 4) > 15
Enter the gene id you wish to make active for the first timestep > 1

```

In order to create a lineage tree, you have to define a gene (or node in the network model) to be a left input, and another gene to be a right input. The gene that serves as a left input is turned on (or made active) for the left child of a parent node when it divides or dies, and likewise the gene that serves as a right input is turned on for the right child of a parent node when it divides or dies. In addition, you have to define a gene that causes division, a gene that causes differentiation and a gene that causes death. From the above screen, we are setting gene 1 which is “101323” to be a left input gene, gene 6 which is “0122210” to be a right input gene, gene 10 which is “233122” to be a gene that causes division, gene 0 which is “223231” to be a gene that causes differentiation and gene 15 which is “101312” to be a gene that causes death. Finally, gene 1 is set to be the node that is turned on for the first timestep.

In the default model, if the node that controls division is active before cells that cause differentiation and death, then the cell will divide. However if this node is not active, then the next node that will be inspected will be the node that controls differentiation. Finally if the node that causes differentiation is not active, then the node that causes death will be examined. If neither of these are active, then the cell remains a precursor cell.

The next screen shows that the lineage tree being created.

```

C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar
8. 312000
9. 231230
10. 233122
11. 231331
12. 031031
13. 011223
14. 130201
15. 101312
16. 230032
17. 010122
Enter the gene id you wish to make as left input (e.g. 0) > 1
Enter the gene id you wish to make as right input (e.g. 1) > 6
Enter the gene id you wish to make as division output node (e.g. 2) > 10
Enter the gene id you wish to make as differentiate output node (e.g. 3) > 0
Enter the gene id you wish to make as death output node (e.g. 4) > 15
Enter the gene id you wish to make active for the first timestep > 1
Lineage Model created!

-- 3Models Framework Demo App --
1. Create artificial genome (specifying sequence)
2. Create artificial genome (randomly)
3. Create network form artificial genome
4. Create lineage tree from network
5. Build lineage tree to depth N
6. Traverse lineage tree
7. View expression graph for cell N
8. View stats for cell N
9. View artificial genome sequence
10. View network
11. Save simulation
Select option, or enter 0 to quit > 6_

```

The current lineage tree can be traversed using option 6. This is an inorder traversal of the lineage tree. The output of this traversal is shown in the next screen.

```

C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar
5. Build lineage tree to depth N
6. Traverse lineage tree
7. View expression graph for cell N
8. View stats for cell N
9. View artificial genome sequence
10. View network
11. Save simulation
Select option, or enter 0 to quit > 6
The current tree is
2():1 1(Div):1 3():1
The parent cell is 1
Current depth is 1
Number of cells is 3

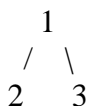
-- 3Models Framework Demo App --
1. Create artificial genome (specifying sequence)
2. Create artificial genome (randomly)
3. Create network form artificial genome
4. Create lineage tree from network
5. Build lineage tree to depth N

```

The output shown is 2():1 1(Div):1 3():1

This means that 2 is a precursor cell because there is nothing in between the brackets. A (D) means the cell has differentiated. A (Div) means the cell has divided and an (X) means the cell has died. The digit to the right of the colon is the parent. Therefore 2 is a precursor cell whose parent has an id of 1. Cell 1 is the zygote as the parent is the same as itself, i.e. 1. Cell 3 is also a precursor cell and its parent is cell 1.

If this were shown in a tree it would appear as follows.



The current depth of the tree is also shown, which is 1 and the total number of cells which is 3.

The expression graph for cells can also be viewed. To view the gene expression graph for the zygote, i.e. cell 1, the option to select would be 7. This is shown in the next screen.

```

C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar

-- 3Models Framework Demo App --
1. Create artificial genome (specifying sequence)
2. Create artificial genome (randomly)
3. Create network from artificial genome
4. Create lineage tree from network
5. Build lineage tree to depth N
6. Traverse lineage tree
7. View expression graph for cell N
8. View stats for cell N
9. View artificial genome sequence
10. View network
11. Save simulation

Select option, or enter 0 to quit > 7
The current tree is
  2():1 1(Div):1 3():1
The parent cell is 1
Current depth is 1
Number of cells is 3
Enter cell id (e.g. 1 for zygote) > 1

```

The tree is traversed inorder and displayed along with the details mentioned previously. Once the enter key is pressed, the following screen is displayed for cell 1.

```

C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar

Number of cells is 3
Enter cell id (e.g. 1 for zygote) > 1
Gene 223231 18 | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 101323 19 -> 28:T 30:T | 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 131222 20 | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 222133 21 -> 27:T | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 031213 22 -> 27:T 33:T | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 300132 23 -> 25:T | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 012210 24 -> 18:T 27:T | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 032012 25 | 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 312000 26 -> 29:T | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 231230 27 | 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 233122 28 -> 25:T | 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 231331 29 | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 031031 30 -> 27:T 28:T | 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 011223 31 -> 34:T | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 130201 32 | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 101312 33 -> 25:T | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 230032 34 | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gene 010122 35 | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

```

The above screen shows the gene expression graph for the zygote. At timestep 1 it can be seen that gene 101323 was turned on (i.e. a 1). At the next timestep, timestep 2, gene 233122 (i.e. id 28) was active which caused the zygote to divide. This gene was earlier set to be the gene that causes division when active.

Further information about the cell can be found in option 8 which is shown in the next screen.

```

C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar
8. View stats for cell N
9. View artificial genome sequence
10. View network
11. Save simulation

Select option, or enter 0 to quit > 8
The current tree is
  2():1 1(Div):1 3():1
The parent cell is 1
Current depth is 1
Number of cells is 3
Enter cell id (e.g. 1 for zygote) > 1
--- Cell 1 ---
Cell divided!
Occured at timestep upon creation : 2
Timesteps from zygote : 0

-- 3Models Framework Demo App --
1. Create artificial genome (specifying sequence)
2. Create artificial genome (randomly)
3. Create network form artificial genome

```

The tree is traversed inorder and displayed along with the details mentioned previously. The information for cell 1 shows that the cell has divided at timestep 2. The total timesteps from the zygote is 0, since cell 1 in this case is the zygote itself.

The lineage tree can be built up to a certain depth or until all cells have either differentiated or died, whichever comes first. This option is available as option 5, as shown in the next screenshot.

```

C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar
Enter the gene id you wish to make as left input (e.g. 0) > 1
Enter the gene id you wish to make as right input (e.g. 1) > 6
Enter the gene id you wish to make as division output node (e.g. 2) > 10
Enter the gene id you wish to make as differentiate output node (e.g. 3) > 0
Enter the gene id you wish to make as death output node (e.g. 4) > 15
Lineage Model created!

-- 3Models Framework Demo App --
1. Create artificial genome (specifying sequence)
2. Create artificial genome (randomly)
3. Create network form artificial genome
4. Create lineage tree from network
5. Build lineage tree to depth N
6. Traverse lineage tree
7. View expression graph for cell N
8. View stats for cell N
9. View artificial genome sequence
10. View network
11. Save simulation

Select option, or enter 0 to quit > 5
Enter depth of tree (e.g. 5) > 2

```

The depth specified is 2, which results in 7 cells being created in the model. This is shown in the next screen.

```

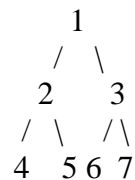
C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar
9. View artificial genome sequence
10. View network
11. Save simulation

Select option, or enter 0 to quit > 5
Enter depth of tree (e.g. 5) > 2
The current tree is
4():2 2(Div):1 5():2 1(Div):1 6():3 3(Div):1 7():3
The parent cell is 1
Current depth is 2
Number of cells is 7

-- 3Models Framework Demo App --
1. Create artificial genome (specifying sequence)
2. Create artificial genome (randomly)
3. Create network form artificial genome
4. Create lineage tree from network
5. Build lineage tree to depth N
6. Traverse lineage tree
7. View expression graph for cell N
8. View stats for cell N
9. View artificial genome sequence
10. View network

```

The tree looks like the following



Cells 1, 2 and 3 have divided.

The results of the simulation can be saved using option 11. The next screen shows the results being saved in *results.txt*. This file is stored in the same directory as the application.

```

C:\WINDOWS\system32\cmd.exe - java -jar 3Models.jar
3. Create network form artificial genome
4. Create lineage tree from network
5. Build lineage tree to depth N
6. Traverse lineage tree
7. View expression graph for cell N
8. View stats for cell N
9. View artificial genome sequence
10. View network
11. Save simulation

Select option, or enter 0 to quit > 11
Enter name of file to write to > results.txt
4():2 2(Div):1 5():2 1(Div):1 6():3 3(Div):1 7():3
File written!

-- 3Models Framework Demo App --
1. Create artificial genome (specifying sequence)
2. Create artificial genome (randomly)
3. Create network form artificial genome
4. Create lineage tree from network
5. Build lineage tree to depth N
6. Traverse lineage tree
7. View expression graph for cell N

```

The file can now be opened in any text editor and have its results examined. The output of this file is shown in the next screen.

```

results.bct - Notepad
File Edit Format View Help
222002220001100330310113332003033211201333130102300102000021030320013223310103131323333320323302121120213310212
01201303200121320301133122002113122033100022331131010202233112020213230012303321022320003122312130322320120000
333131013302223320311030201032213220210222032322211233123300030232323103202013001231110333300113201300002232112
3233310331213312313111313013031333211123023230031122133330121022003320202301133201313311033021323130300011322121
131120320313202323202112120203220320132021201001133130301003321011032101333020332101121133303330011133120320132
231302131120003230222210030222111333111321222333313233203210201330313002003010202032321233211311100102320021
3132103331232023103112202322030113123232013333000230330132001320212102102233113322133200133110203133020100220212
2202130020132012320130211330232213031220110003310320310311330320201230021121320130310320013012301130010031233123
121123002203200323323031103213233132233103213013331301222322101133312300301322112322311022203002113023113002211
1110023000033210200211020212311121333222111201200211133323203120003223330021032212210020311213313330101231230331
03323111310133133312022123033132122323112331013210100131300322033023321321203000313123130302132121103132033131
213222020020222102102113000303003103101222202233302120221030121330131331132222112021223333023120313023133033000
23113301231030332201310002320232200112111221110111322120130313033132120102012133121302201003311101313022122202
3130212221013303112332223113310210022031002002313131000312010123312200203111323122213332210023111323320133123203
000023110331330332301012313311012021313321331101031113210201301330132032020202123221203003130200120001312021122
2301112111010023030013010200311000320132213311213311123111000013302020113221200131113133112020323200133333300
0310123232120203121111013312333231003330233013301112020302001232130331132200122101323100330020031012103200300
3213000022010310103103130130322321223301010112230312331302133113323233032200010113020103310022221031323211331
0020012213203201002001310032220223133002220221022301030321103311023200303222311310010110131202131300331203012233
023301221023012331203221032000221210230301310020321032311333132321231022121230323011213302003230311112300301200
0001012300320100023312333030110100121010210122110220012113212130002211123102000122321203320310000123110310002123
22203321310010101122022210331212322111230133021013021131230102303132203023110130011013123210103102311321212220
1223110310003303100122223133231110233212030301122200110013021330022001112100330220302120121211220103311320320000
12020233310032030223230221201210020123200102322221023313102233223001021321033113201210310003123322101112300003
310120022133101112120322233233030301321212302302002103233303212313213120123113013010301113013303120320302031133
0323102133033000112321033011230022323202130112102221333312332113103313
Seed is 0
Simulated lineage tree results
4():2 2(Div):1 5():2 1(Div):1 6():3 3(Div):1 7():3
The parent cell is 1
Current depth is 2
Number of cells is 7

--- Cell 1 ---
Cell divided!
Occurred at timestep upon creation : 2
Timesteps from zygote : 0

Gene 223231 18          |0 0 0 0 0 0 0 0 0
Gene 101323 19 -> 28:T 30:T |1 0 0 0 0 0 0 0 0
Gene 131222 20          |0 0 0 0 0 0 0 0 0
Gene 222133 21 -> 27:T   |0 0 0 0 0 0 0 0 0
Gene 031213 22 -> 27:T 33:T |0 0 0 0 0 0 0 0 0
Gene 300132 23 -> 25:T   |0 0 0 0 0 0 0 0 0
Gene 012210 24 -> 18:T 27:T |0 0 0 0 0 0 0 0 0
Gene 032012 25          |0 0 1 1 0 0 0 0 0
Gene 312000 26 -> 29:T   |0 0 0 0 0 0 0 0 0
Gene 231230 27          |0 0 1 0 0 0 0 0 0
Gene 233122 28 -> 25:T   |0 1 1 0 0 0 0 0 0
Gene 231331 29          |0 0 0 0 0 0 0 0 0
Gene 031031 30 -> 27:T 28:T |0 1 0 0 0 0 0 0 0
Gene 011223 31 -> 34:T   |0 0 0 0 0 0 0 0 0
Gene 130201 32          |0 0 0 0 0 0 0 0 0
Gene 101312 33 -> 25:T   |0 0 0 0 0 0 0 0 0
Gene 230032 34          |0 0 0 0 0 0 0 0 0
Gene 010122 35          |0 0 0 0 0 0 0 0 0

--- Cell 2 ---
Cell divided!
Occurred at timestep upon creation : 2

```

Gene expression graphs for all cells are generated along with useful statistics.

2.3. Running additional simulations

Once the lineage tree has been built, simulations can be run to create trees of increasing depth. A new lineage tree can also be generated from the current network if new inputs and outputs are to be changed, and subsequently simulated using the build option. If a new AG model is created, the network model is not automatically nor is the lineage tree. Therefore if a new AG model is created, a new network has to be created as well in addition to the lineage tree model.

The application is currently only a basic prototype showing most of the allowing the user to perform simple simulations. The application can be expanded to allow for a graphical user interface to be built on top of the existing code. Please refer to the final report on the architecture used in structuring the framework.

3. Credits

This software was developed by Chooi Guan Lim at the University of Queensland.