Bioinformatics III

Sixth Assignment

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May 30, 2018

Exercise 6.1: Boolean Networks

All the listings are at the end of the exercise.

(a) **Weighted Interactions**

Table 1: Propagation Matrix

	F	E	D	C	B	A
F	0	0	1	0	0	0
E	1	0	0	0	0	0
D	-3	-3	0	0	-3	0
C	0	1	0	0	1	0
B	0	0	0	1	0	0
A	0	0	0	0	1	1

(b) **Implementation**

When does it make sense to stop the propagation and why?

We stop the propagation once we meet an already visited state. If we continue, we will just loop over and over again.

Which sequences do you get when you start from states 1, 4, 21, and 33?

Sequence with starting state 1: [1, 3, 7, 23, 55, 63, 13, 1]
Sequence with starting state 4: [4, 18, 36, 26, 4]
Sequence with starting state 21: [21, 51, 47, 13, 1, 3, 7, 23, 55, 63, 13]
Sequence with starting state 33: [33, 11, 5, 19, 39, 31, 5]

(c) **Periodic Orbits**
   (1) List these orbits with their respective lengths and basins of attraction

   To make things clearer let's recall the different definition. "If the attractor has only a single state it is called a point attractor, and if the attractor consists of more than one state it is called a cycle attractor. The set of states that lead to an attractor is called the basin of the attractor. States which occur only at the beginning of trajectories (no trajectories lead to them), are called garden-of-Eden states" [1]

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[1] https://en.wikipedia.org/wiki/Boolean_network#Attractors

Table 2: List of states, orbith length, Cycle attractor and relative coverage of the basin of attraction. The basin of attraction's coverage includes the steps before the cycle attractor.

Start State	Period	Basin	Attractor	Basin Coverage
0	1	[]	[0]	1.5625%
1	7	[]	[1, 3, 7, 23, 55, 63, 13]	10.9375%
2	4	[2]	[4, 18, 36, 26]	7.8125%
3	7	[]	[3, 7, 23, 55, 63, 13, 1]	10.9375%
4	4	[]	[4, 18, 36, 26]	6.25%
5	4	[]	[5, 19, 39, 31]	6.25%
6	1	[6, 22, 54, 62, 12]	[0]	9.375%
7	7	[]	[7, 23, 55, 63, 13, 1, 3]	10.9375%
8	1	[8]	[0]	3.125%
9	7	[9]	[1, 3, 7, 23, 55, 63, 13]	12.5%
10	4	[10]	[4, 18, 36, 26]	7.8125%
11	4	[11]	[5, 19, 39, 31]	7.8125%
12	1	[12]	[0]	3.125%
13	7	[]	[13, 1, 3, 7, 23, 55, 63]	10.9375%
14	4	[14]	[4, 18, 36, 26]	7.8125%
15	4	[15]	[5, 19, 39, 31]	7.8125%
16	1	[16, 32, 8]	[0]	6.25%
17	4	[17, 35, 15]	[5, 19, 39, 31]	10.9375%
18	4	[]	[18, 36, 26, 4]	6.25%
19	4	[]	[19, 39, 31, 5]	6.25%
20	1	[20, 50, 44, 8]	[0]	7.8125%
21	7	[21, 51, 47]	[13, 1, 3, 7, 23, 55, 63]	15.625%
22	1	[22, 54, 62, 12]	[0]	7.8125%
23	7	[]	[23, 55, 63, 13, 1, 3, 7]	10.9375%
24	1	[24]	[0]	3.125%
25	7	[25]	[1, 3, 7, 23, 55, 63, 13]	12.5%
26	4	[]	[26, 4, 18, 36]	6.25%
27	4	[27]	[5, 19, 39, 31]	7.8125%
28	1	[28]	[0]	3.125%
29	7	[29]	[1, 3, 7, 23, 55, 63, 13]	12.5%
30	4	[30]	[4, 18, 36, 26]	7.8125%
31	4	[]	[31, 5, 19, 39]	6.25%
32	1	[32, 8]	[0]	4.6875%
33	4	[33, 11]	[5, 19, 39, 31]	9.375%
34	1	[34, 12]	[0]	4.6875%
35	4	[35, 15]	[5, 19, 39, 31]	9.375%
36	4	[]	[36, 26, 4, 18]	6.25%
37	4	[37, 27]	[5, 19, 39, 31]	9.375%
38	4	[38, 30]	[4, 18, 36, 26]	9.375%
39	4	[]	[39, 31, 5, 19]	6.25%
40	1	[40, 8]	[0]	4.6875%

Start State	Period	Basin	Attractor	Basin Coverage
41	7	[41, 9]	[1, 3, 7, 23, 55, 63, 13]	14.0625%
42	1	[42, 12]	[0]	4.6875%
43	7	[43]	[13, 1, 3, 7, 23, 55, 63]	12.5%
44	1	[44, 8]	[0]	4.6875%
45	7	[45, 9]	[1, 3, 7, 23, 55, 63, 13]	14.0625%
46	1	[46, 12]	[0]	4.6875%
47	7	[47]	[13, 1, 3, 7, 23, 55, 63]	12.5%
48	1	[48, 40, 8]	[0]	6.25%
49	7	[49, 43]	[13, 1, 3, 7, 23, 55, 63]	14.0625%
50	1	[50, 44, 8]	[0]	6.25%
51	7	[51, 47]	[13, 1, 3, 7, 23, 55, 63]	14.0625%
52	1	[52, 58, 12]	[0]	6.25%
53	7	[53, 59]	[13, 1, 3, 7, 23, 55, 63]	14.0625%
54	1	[54, 62, 12]	[0]	6.25%
55	7	[]	[55, 63, 13, 1, 3, 7, 23]	10.9375%
56	1	[56, 8]	[0]	4.6875%
57	7	[57, 9]	[1, 3, 7, 23, 55, 63, 13]	14.0625%
58	1	[58, 12]	[0]	4.6875%
59	7	[59]	[13, 1, 3, 7, 23, 55, 63]	12.5%
60	1	[60, 8]	[0]	4.6875%
61	7	[61, 9]	[1, 3, 7, 23, 55, 63, 13]	14.0625%
62	1	[62, 12]	[0]	4.6875%
63	7	[]	[63, 13, 1, 3, 7, 23, 55]	10.9375%

(2) Give the relative coverages of the state space by the basins of attraction.
The coverages for each separate basins of attraction are given in the table 2. In table 3 we give the coverage of each attractor.

Table 3: Relative coverage of the cycle attractors

[0] :	23	:	35.9375 %
[1, 3, 7, 13, 55, 23, 63] :	21	:	32.8125 %
[18, 26, 4, 36] :	9	:	14.0625 %
[39, 19, 5, 31] :	11	:	17.1875 %

(d) **Interpretation**

Listing 1: Output - Binary evolution in the orbits and percentages

```
 0  Current orbit:    [0]
    Binary evolution:
    [0, 0, 0, 0, 0, 0]
    Average occupancy:
     [0.0, 0.0, 0.0, 0.0, 0.0, 0.0]
 5
    Current orbit:    [1, 3, 7, 23, 55, 63, 13]
    Binary evolution:
    [0, 0, 0, 0, 0, 1]
    [0, 0, 0, 0, 1, 1]
10  [0, 0, 0, 1, 1, 1]
    [0, 1, 0, 1, 1, 1]
    [1, 1, 0, 1, 1, 1]
    [1, 1, 1, 1, 1, 1]
    [0, 0, 1, 1, 0, 1]
15  Average occupancy:
     [0.2857142857142857, 0.42857142857142855, 0.2857142857142857,
         0.7142857142857143, 0.7142857142857143, 1.0]

    Current orbit:    [4, 18, 36, 26]
    Binary evolution:
20  [0, 0, 0, 1, 0, 0]
    [0, 1, 0, 0, 1, 0]
    [1, 0, 0, 1, 0, 0]
    [0, 1, 1, 0, 1, 0]
    Average occupancy:
25   [0.25, 0.5, 0.25, 0.5, 0.5, 0.0]

    Current orbit:    [5, 19, 39, 31]
    Binary evolution:
    [0, 0, 0, 1, 0, 1]
30  [0, 1, 0, 0, 1, 1]
    [1, 0, 0, 1, 1, 1]
    [0, 1, 1, 1, 1, 1]
    Average occupancy:
     [0.25, 0.5, 0.25, 0.75, 0.75, 1.0]
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Exercise 6.2: Differential Expression Analysis

(a) **A**

(b) **B**