Bioinformatics III

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Exercise Sheet 5

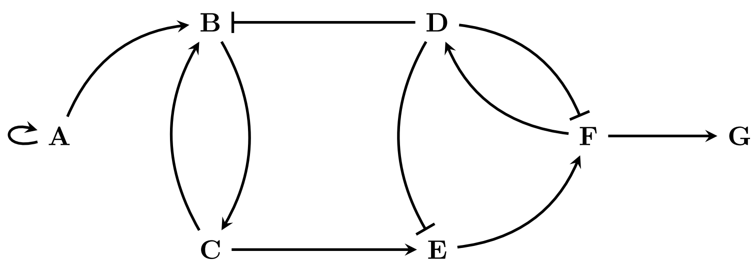
Due: 30.11.2012 13:15

Send your solutions via email with a single PDF attachment. If possible, please include source code listings. Alternatively, you may submit your solutions on paper (hand-written or printed) at the beginning of the lecture or in building E2 1, Room 3.03. Additionally, hand in all source code via mail to nschaadt@bioinformatik.uni-saarland.de.

Boolean Networks and Graph Connectivity

Exercise 5.1: Boolean Network (65 points)

Consider the following network, which describes the mutual regulation of the hypothetical genes **A** to **G**. A line with an arrowhead denotes an activation while a flat end denotes an inhibition, i.e., if **A** is high, **B** is activated, whereas high levels of **D** inhibit the expression of **B**.



To investigate the behavior of this network use a dynamic simulation as introduced in lecture 9, pp. 23-25 with a synchronous update scheme.

Assume that an activation has a weight of 1, while an inhibition is always 3 times stronger than an activation. Set all thresholds to 0.

(a) **Weighted Interactions (10)**
Set up the propagation matrix that relates the states of the genes **A** to **G** in the next iteration to the current state.

(b) **Implementation (20)**
Write a program to simulate the Boolean network.

To enumerate the initial states, convert the binary levels of the genes into an integer where **A** determines the least significant bit and **G** the most significant one. An initial state where, e.g., only **A**, **C**, and **D** are on high levels would translate into $1 + 4 + 8 = 13$.

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

(2) Which sequences do you get when you start from states 6, 17, 20, 21, and 85?

(c) **Periodic Orbits (20)**
To determine the attractors and the corresponding basins of attraction, go through all possible initial states and save at which state the Boolean network closes its orbit.

(1) List these orbits with their respective lengths and basins of attraction.

(2) Give the relative coverages of the state space by the basins of attraction.

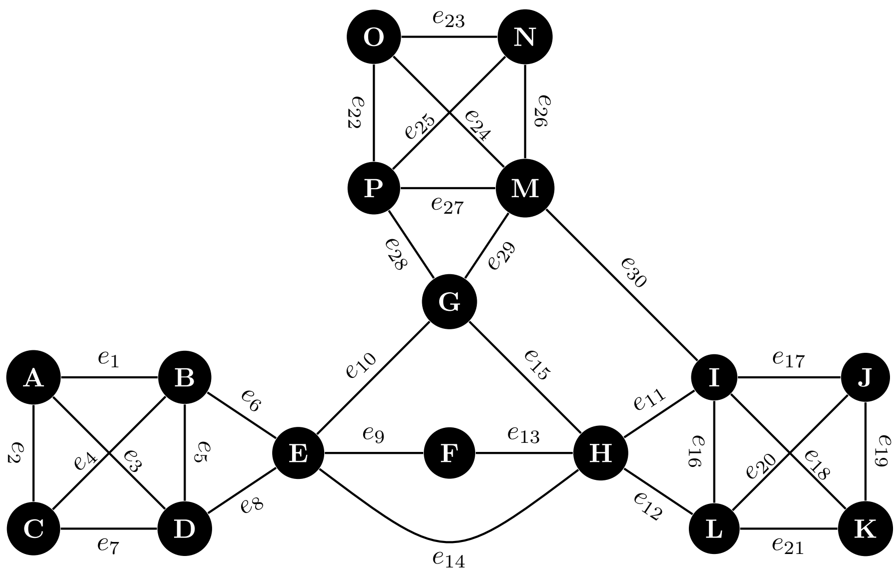
(d) **Interpretation (15)**

(1) Give the attractors in terms of active genes and characterize them with a few words.

(2) Which are the special genes and what are their respective effects on the behavior of the network? For this, explain what is determining the period of the orbits. Further, compare the two shorter orbits with each other. Which gene is responsible for the difference?

Exercise 5.2: Graph Connectivity (35 points)

(a) Consider the graph G_1 shown below.



(1) **Edge Cut (10)**
Consider all edge cuts of $G_1 = (V_1, E_1)$. Is there any cut edge? List all minimal and all minimum size edge cuts.

(2) **Vertex Connectivity (10)**
List all minimal vertex cuts of G_1. Is there any cut vertex? Give the vertex connectivity of G_1.

(3) **Partition Cut (5)**
Give the partition cut of G_1 for the partitions $X = \{A, B, C, D, E\}$ and $Y = V_1 \setminus X$.

(b) **Edge Connectivity (10)**

Give the edge connectivity of the graphs $G_2 = (V, E)$ and $G_3 = (V, E)$ which statisfy each of the following conditions simultaneously:

(1) G_2 and G_3 are connected

(2) $|V| > 3$

(3) $\forall v, w \in V$ there is a cycle containing v and w

(4) $\forall v \in V, e \in E$ there is a cycle containing v and e

(5) $\forall e, f \in E$ there is a cycle containing e and f

(6) $\forall v, w \in V, e \in E$ there is a path from v to w containing e

(7) $\forall u, v, w \in V$ there is a path from u to v containing w

(8) $\forall u, v, w \in V$ there is a path from u to v not containing w

(9) $|E|$ of G_2 should be minimal and $|E|$ of G_3 maximal

Have fun!