

Influence of update schemes on gene regulatory networks

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Abstract—In this paper we will introduce boolean networks (BN) and their relevance to gene regulatory networks (GRN). We will have a closer look on update schemes. Specifically, synchronous, sequential and asynchronous update schemes and their effect on the behavior of BN and GRN respectively.

1 INTRODUCTION

Possible points to mention here:

- Explain shortly gene regulatory networks (GRN)
- Explain why boolean networks are used to model GRN
- Maybe mention history of boolean networks
- Set the focus to the update scheme as it seems to be rarely covered in the field of GRNs
- Possible open question about which update scheme might be best to model GRNs. Answer to this must follow in the conclusion

2 BOOLEAN NETWORKS

Explain Boolean network and what an update scheme is using the synchronous/parallel scheme. Also use figure, e.g. fig. 1 to further visualize and create a better understanding of boolean networks. Also explain what chaotic behavior is due its relevance for the update schemes.

2.1 Notation

Define clear notation used throughout the paper. Position of this subsection could change to be part of the Introduction instead.

3 UPDATE SCHEMES

Explain different update schemes including characteristics for behavior especially chaotic behavior. These will mostly focus on boolean networks only. Maybe mention of use-cases for each update scheme.

3.1 Synchronous scheme

The Synchronous (also known as Parallel) update scheme assumes that every node is updated at once.

3.2 Sequential scheme

close to synchronous. the nodes update in a specific order and take into account the updated input node if that node had been updated before/is positioned earlier in the sequence

3.3 Block-sequential scheme

mix of synchronous and sequential. predefined blocks update sequential, inside a block the update follows the synchronous scheme

3.4 Asynchronous deterministic

one node is updated per tick following a specific sequence

3.5 Asynchronous generalized

same as asynchronous deterministic with the slight change that within the sequence nodes may appear multiple times.

4 RELEVANCE FOR GENE REGULATORY NETWORKS

Tie the update schemes and their different outcomes or behavior to GRN.

Emphasizing the drawbacks of asynchronous models when applied to GRN e.g. it takes way to long to update a GRN using asynchronous deterministic for it to have an effect; assuming that one update takes a few minutes, when the whole process can take days to complete.[1]

5 CONCLUSION

Not yet included: robustness! might be covered for each update scheme individually.

References: [1][2][3][4][5]

REFERENCES

- [1] Julian D Schwab, Silke D Kühlwein, Nensi Ikononi, Michael Kühl, and Hans A Kestler. Concepts in boolean network modeling: What do they all mean? *Computational and structural biotechnology journal*, 18:571–582, 2020.
- [2] Julio Aracena, Eric Goles, Andrés Moreira, and Luis Salinas. On the robustness of update schedules in boolean networks. *Biosystems*, 97(1):1–8, 2009.

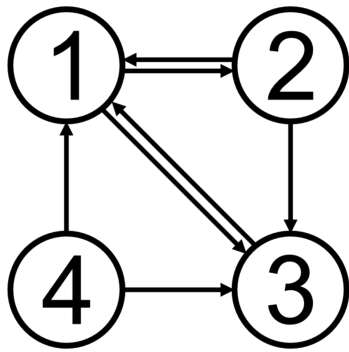


Fig. 1. Boolean example (image will be changed!). Simple boolean network example; a graph of the network and most likely a table as well for the updated states $x(t) \rightarrow x(t + 1)$ (currently missing)

- [3] Stefan Bornholdt. Boolean network models of cellular regulation: prospects and limitations. *Journal of the Royal Society interface*, 5(suppl_1):S85–S94, 2008.
- [4] Eric Goles and Mathilde Noual. Block-sequential update schedules and boolean automata circuits. *Discrete Mathematics & Theoretical Computer Science*, (Proceedings), 2010.
- [5] Tomas Helikar, Naomi Kochi, John Konvalina, and Jim A Rogers. Boolean modeling of biochemical networks. *The Open Bioinformatics Journal*, 5(1), 2011.

Fig. 2. graph of all possible states for a boolean network using a synchronous update scheme

Fig. 3. example graph of boolean network showcasing grouping of specific nodes.