Case Study: Leader Election*

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Abstract. We describe a leader election protocol that should be verified using suitable tools for the verification of graph transformation systems.

A simple leader election protocol (according to Chang und Roberts [1]) works as follows: there is a set of processes arranged in a ring, i.e., every process has a unique predecessor and a unique successor. Furthermore each process has a unique Id and there exists a total order on the Ids (assume that Ids are natural numbers).

The leader will be the process with the smallest Id, however no process knows what is the smallest Id at the start of the protocol. Hence every process generates a message with its own Id and sends it to its successor. A received message with content MId is treated as follows by a process with Id PId:

- if $MId < PId$, then forward the message to the next successor
- if $MId = PId$, then the process declares itself the leader
- If $MId > PId$, then do not pass on the message (or alternatively discard it)

A straightforward specification via graph transformation rules for a ring with three processes (having IDs 1, 2, 3) is given in Figure 1.

Tasks:

- Model this protocol using graph transformation rules. Either assume a fixed number of processes, or generate rings of arbitrary size before starting the protocol, or allow processes to leave and join the system while the protocol is being run. (The last variant has to be treated with care since it might easily lead to incorrect protocols.)
- Validate the protocol (using verification, testing, etc.) and show that there will never be two processes declaring themselves as leaders.
- Possible extension: model and verify the leader election protocol by Itai & Rodeh [2] that lowers that number of messages which are exchanged. (This is presumably quite difficult.)

The tasks should be fairly open and flexible. Hence no specific test cases will be given.

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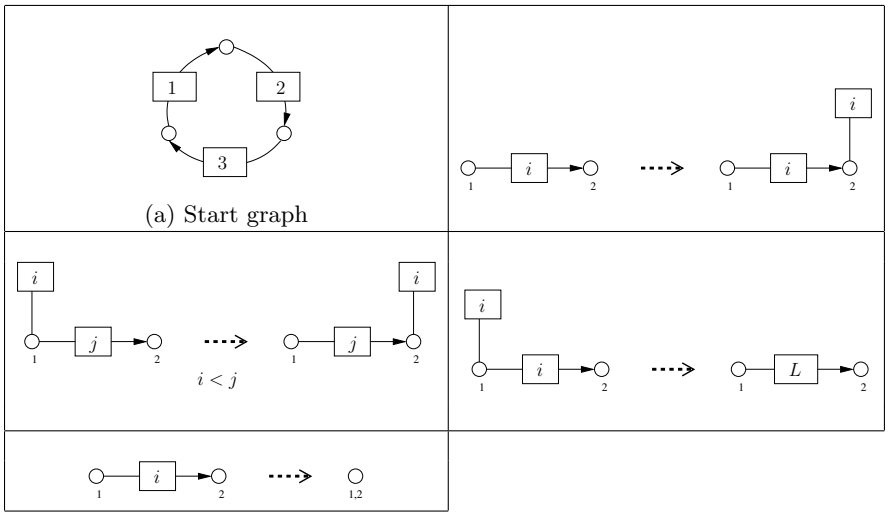

Fig. 1: Leader election (start graph and rewriting rules).

References

1. E.J.H. Chang and R. Roberts. An improved algorithm for decentralized extrema-finding in circular configurations of processes. *Communication of the ACM*, 22(5): 281-283, 1979.
2. A. Itai and M. Rodeh. Symmetry breaking in distributed networks, In *Proceedings of the 22nd IEEE Symposium on Science*, pages 150-158. IEEE Press, 1981.