Detecting and Recovering from Faults in Programmed Molecular Systems

Presented by: Robyn R. Lutz, November 16-17 2015

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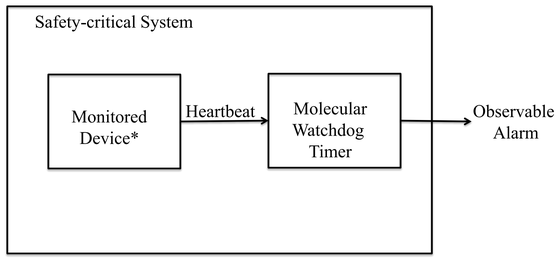
Problem: How can we **detec**t faults when they occur and initiate **recovery**, given that a faulty cyber-molecular system may not report its own failure?

Dual-rail will not work, so we must detect the **absence** of an expected event.

Needs to be a robust, embeddable, and scalable molecular device.

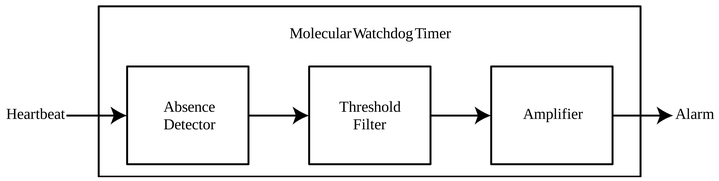
Watchdog timers are used widely in safety-critical computer applications to monitor the health of a system, detect faults, and initiate recovery if the monitored system fails.

- Monitored system sends a periodic heartbeat.
- Watchdog timer detects prolonged absence of heartbeat.
- Watchdog timer issues an alarm and triggers appropriate recovery action.



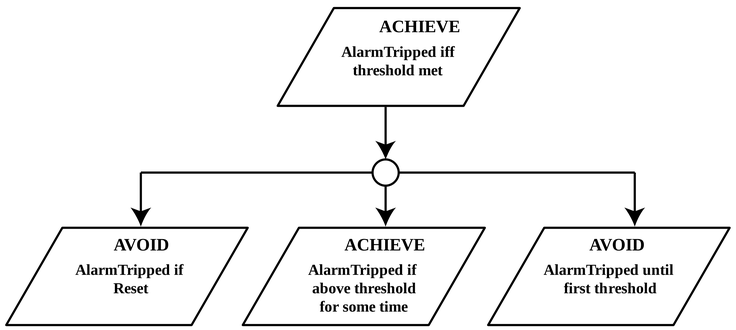
*based on the three-species stochastic Lotka-Volterra oscillator

Solution: Molecular Watchdog Timer (MWT)



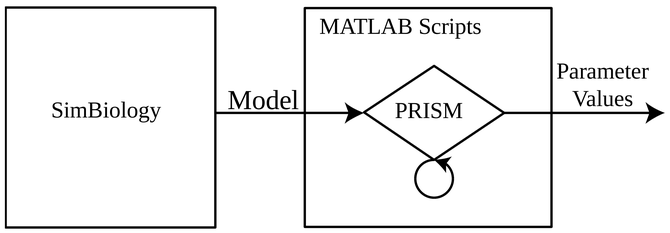
Design

Chemical Reaction Network (CRN) modeling, model-based simulation, probabilistic model checking, and formal proofs used to verify design.

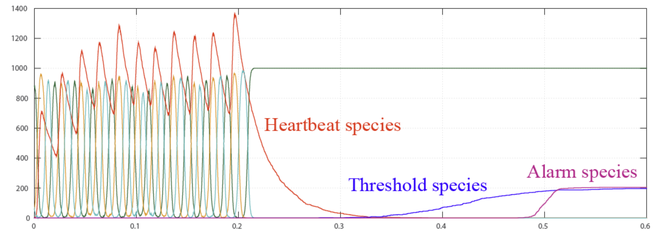


ACHIEVE: Alarm tripped if above threshold for some time.

$$\mathbf{P}_{\geq 1}\Box[Th_h \implies \mathbf{P}_{\geq 1-\eta_4} \Diamond_{\leq w_t h} (A_{trip} \vee \neg Th_h)]$$



Verifying MWT Detects Faults and Initiates Recovery



Used oscillator to test embedding of watchdog timer.

Results: The watchdog timer detects when the monitored system fails and issues an alarm to initiate recovery (reset) of the monitored system.

- Watchdog timer is scalable to realistic molecular counts.
- If the heartbeat stops, the alarm species is produced very quickly, so alarm is reliably triggered.
- Expected time to a false alarm can be as large as desired.
- MWT can be used as a fault-tolerance device and plugged into any system modeled as a CRN.

Potential Impact: Supports the creation of safer cyber-molecular systems.

Reference: Samuel J. Ellis, Eric R. Henderson, Titus H. Klinge, James I. Lathrop, Jack H. Lutz, Robyn R. Lutz, Divita Mathur, Andrew S. Miner: Automated requirements analysis for a molecular watchdog timer. ASE 2014: 767-778.

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An earlier version of this poster was presented at DNA21.