Are Cells Asynchronous Circuits?
(Invited Talk)

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Cells do not seem to have "clocks" in the same sense as synchronous sequential digital circuits. But cells must operate extremely reliably in spite of large amounts of noise and environmental variations which would result in timing variation in a Boolean model of cellular control.

We define timing robustness as the ability of cells to function correctly when there are significant variations in the timing of internal events, and explore timing robustness in cellular control systems using symbolic model checking. For example, we started with an existing model of the control of the budding yeast cell cycle, which was originally evaluated using a completely synchronous model, and checked whether it had the same property in a completely speed-independent model. We found that there were a small number of hazards in the cell cycle control that would cause it to deadlock for some variations in timing, but that all deadlocks could be eliminated by changes in the model that could be justified from the biological literature. Furthermore, model checking with random mutations shows evidence for evolutionary pressure to maintain speed independence.

We then propose a less conservative timing model than speed independence that allows for "fast" and "slow" processes, which is more realistic biologically than complete speed independence and appears to yield reasonable results for more complex models of the cell cycle and some simple examples from developmental biology.

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