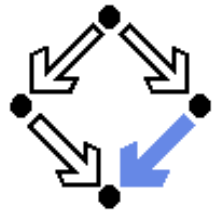
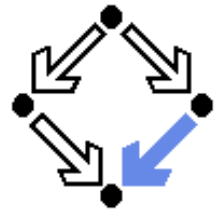
Biological Systems as Concurrent Processes

Wolfgang Schreiner
Wolfgang.Schreiner@risc.uni-linz.ac.at

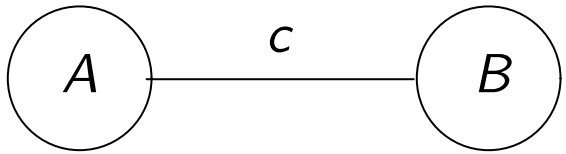
Research Institute for Symbolic Computation (RISC)
Johannes Kepler University, Linz, Austria
http://www.risc.uni-linz.ac.at



Modeling Systems



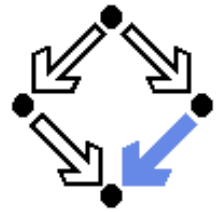
- Software/hardware systems consisting of multiple components:
  - Concurrency: Components execute simultaneously.
  - Interaction: Components may communicate with their neighbors.
  - Mobility: Components may move to another neighborhood.
- May be formally modelled in some calculus.
  - E.g. π-calculus (Milner, 1992).
- Example: components A and B sharing a communication channel c.



  - System: new c $(A \mid B)$.
  - Components: $A := \overline{c}\langle a \rangle.A', B := c(x).B'$.
  - Interaction: new c $(A \mid B) \rightarrow$ new c $(A' \mid B'[a/x])$.

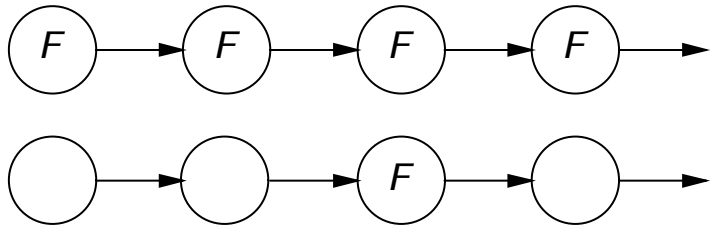
The semantics of a concurrent system is defined by its formal model.

Specifying and Verifying Systems



We may specify properties required from every possible system run.

- Temporal logic:
  - $\Box F$: "F will always hold".
  - $\Diamond F$: "eventually F will hold".

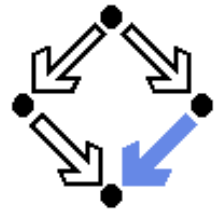


- Specification: $\Box(x > 0 \Rightarrow \Diamond x = 0)$.

  Every time x becomes greater than 0, it will become 0 again.
- Verification: show that every run of a system (e.g. modelled in π-calculus) satisfies a specification (e.g. described in temporal logic).
- Model checking: automatic verification a system that has only a finite number of states.

Similar techniques can be applied to biological systems.

Biological Systems



From the BioSPI project (http://www.wisdom.weizmann.ac.il/~biospi):

We employ 5 major principles in modeling biochemical processes as concurrent systems:

- *Pathways, molecules and molecular domains as computational processes.*
- *Complementary molecular determinants as communication channels.*
- *Molecular interaction and modification as communication and change of channel names.*
- *The integrity of molecules, complexes and compartment as channels with restricted scope.*
- *The formation of complexes and translocation of molecule as extrusion of restricted channels.*

Based on this strong correspondence between the calculus and biochemical networks, we can incrementally represent detailed information on biochemical systems in a structured, biologically faithful fashion. The resulting representations can be used in simulation, analysis and verification.