

# Petri Net Based System Analysis



Brandenburg  
University of Technology  
Cottbus

Monika Heiner, Martin Schwarick, Fei Liu, Mostafa Herajy,  
Christian Rohr (guest), Sigrid Schenk (secretary)

Brandenburg University of Technology at Cottbus, Computer Science Dept.  
= Data Structures and Software Dependability =

## Model-based System Analysis

### Verification of Technical Systems

- requirements certification
- quality improvement
- proof engineering

#### Typical Net properties

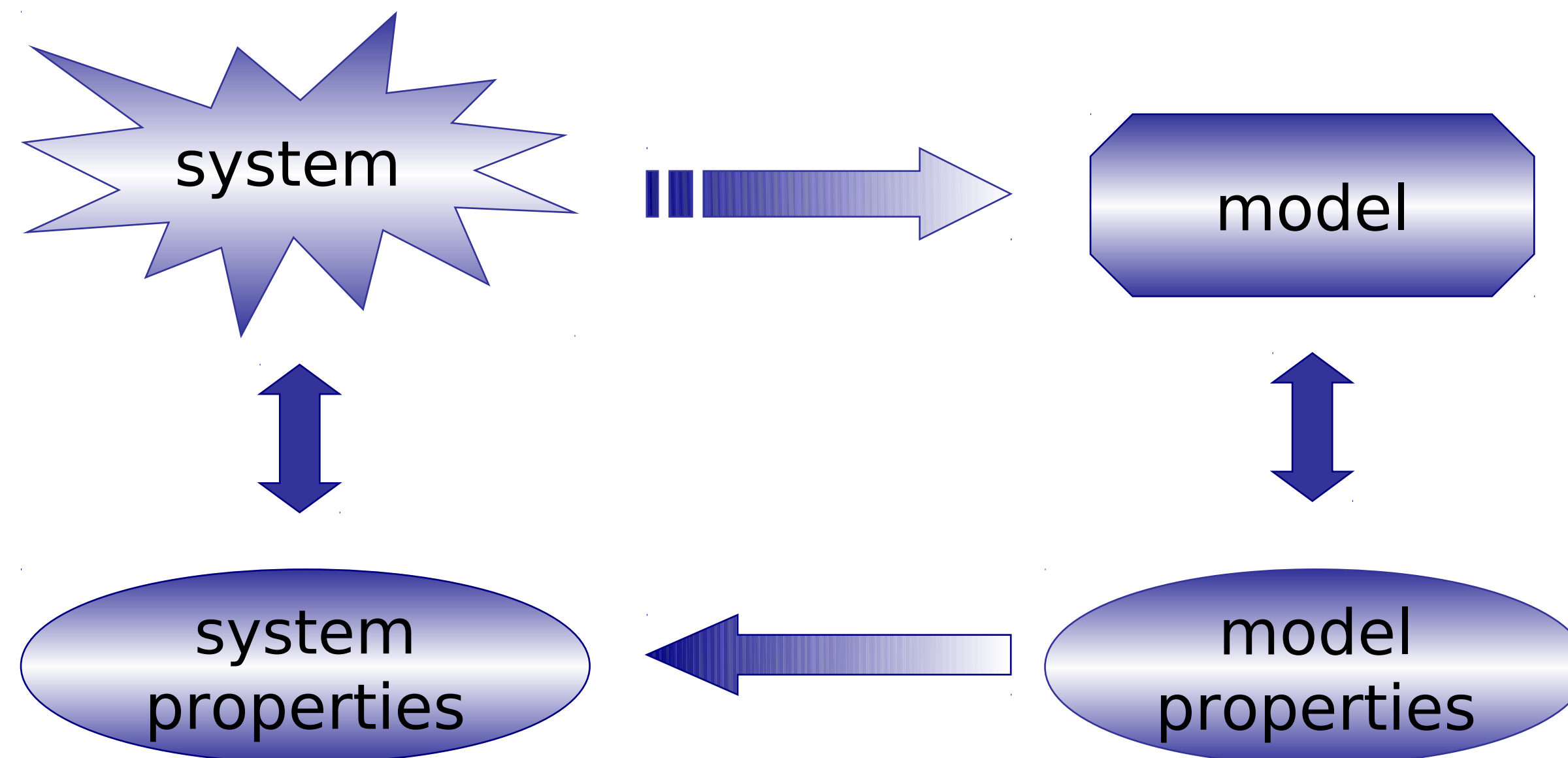
- ordinary
- 1-bounded
- live, reversible
- communicating state machines
- exponential, state space growth

### Validation of Natural Systems

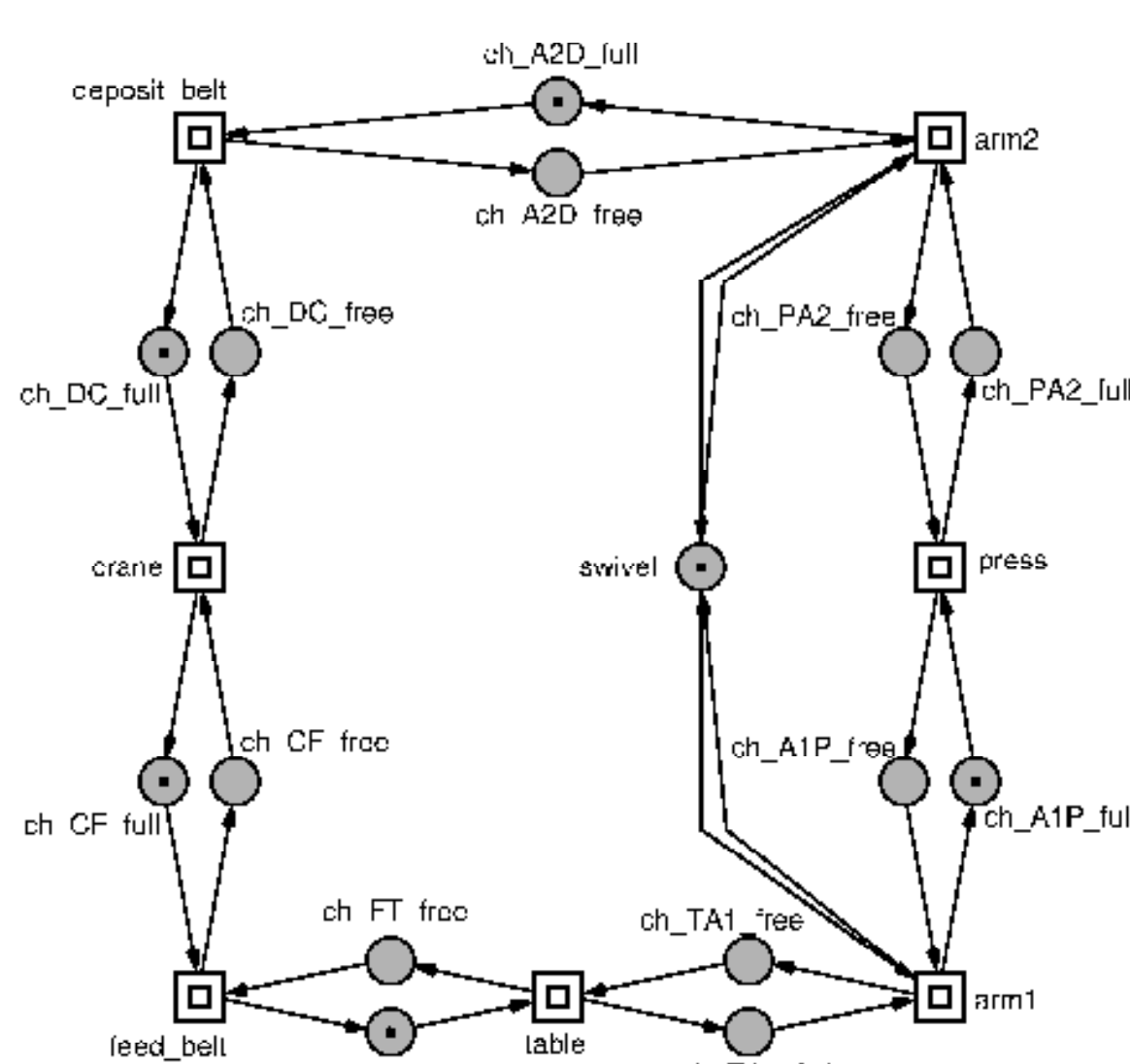
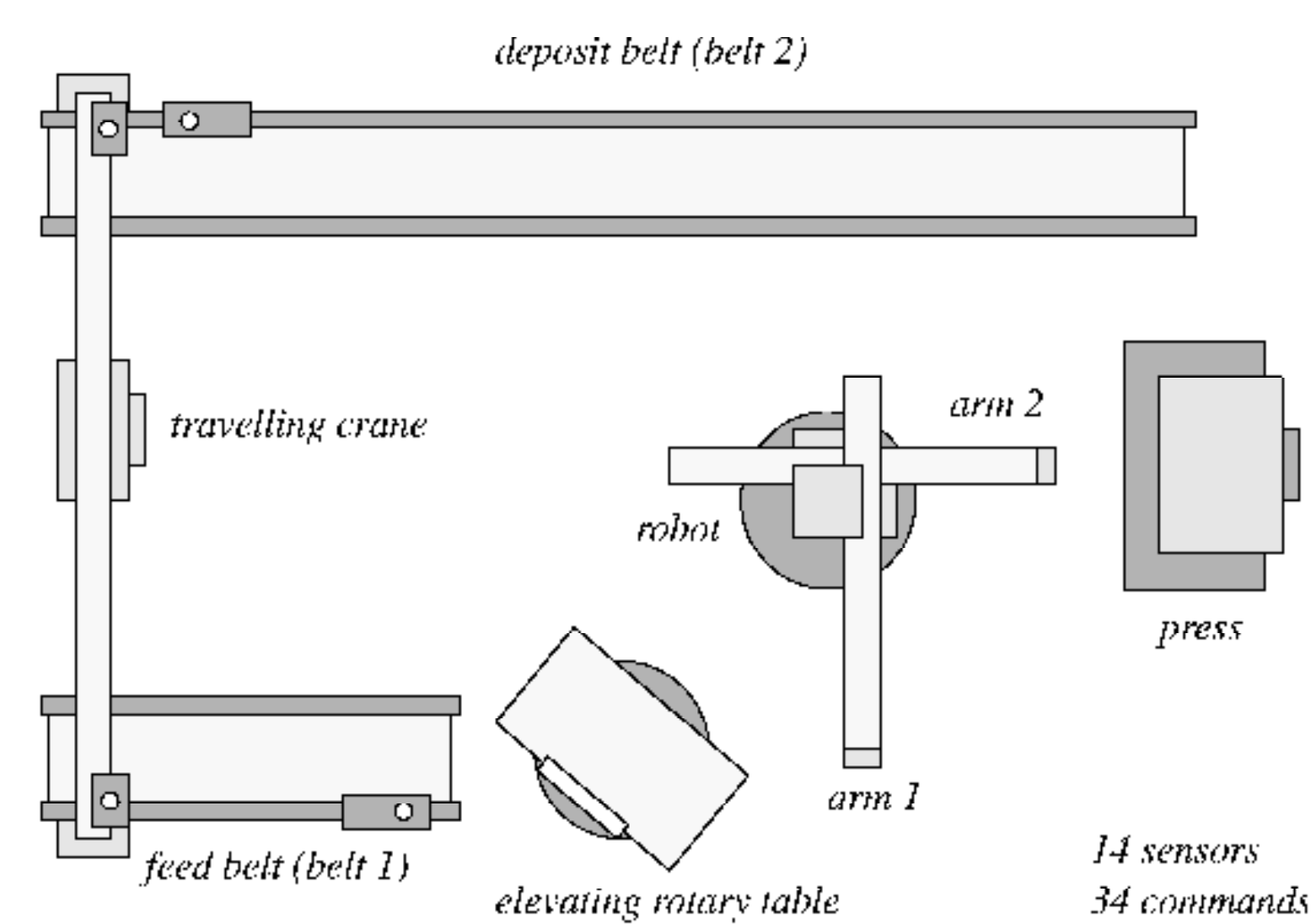
- understanding
- experiment design
- behaviour prediction

#### Typical Net properties

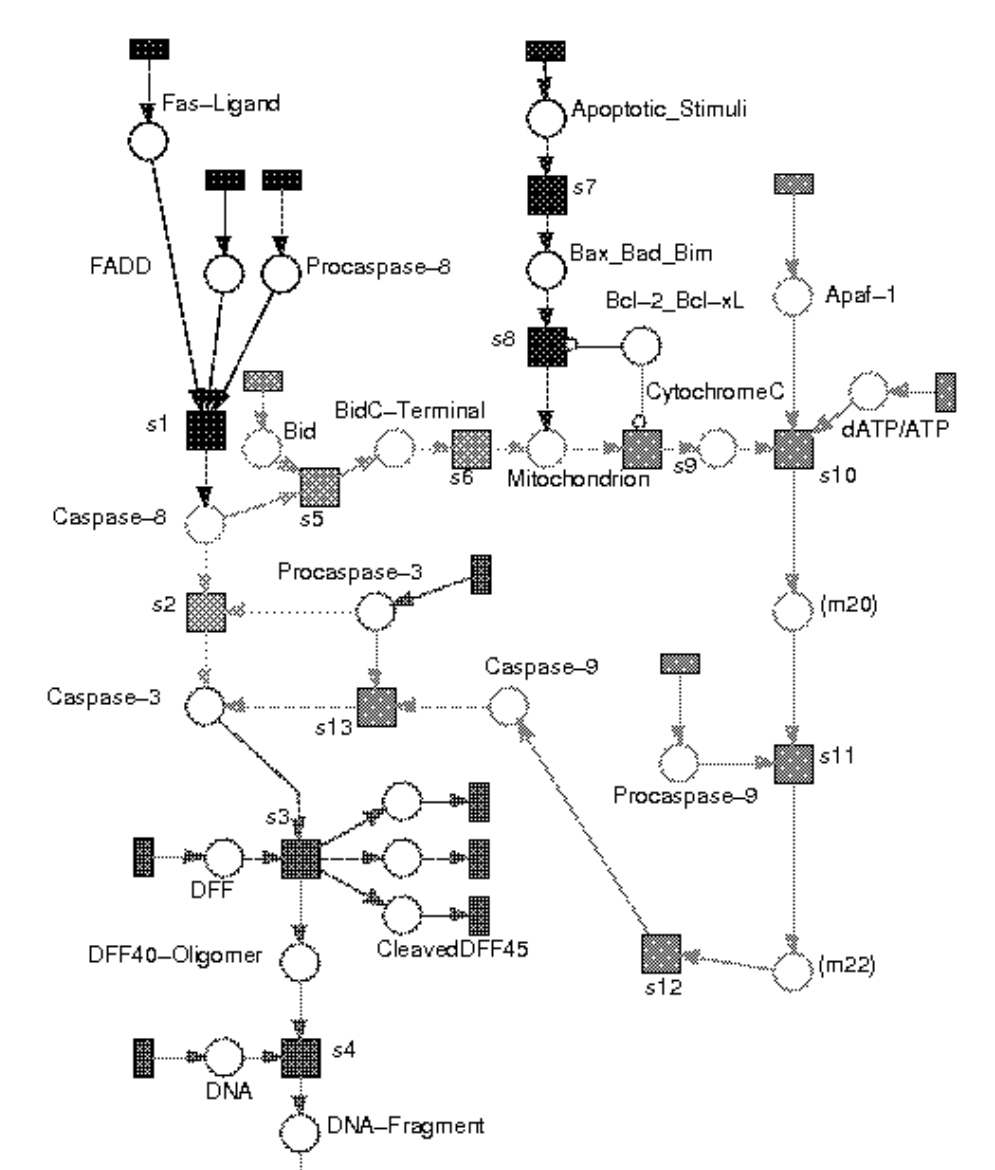
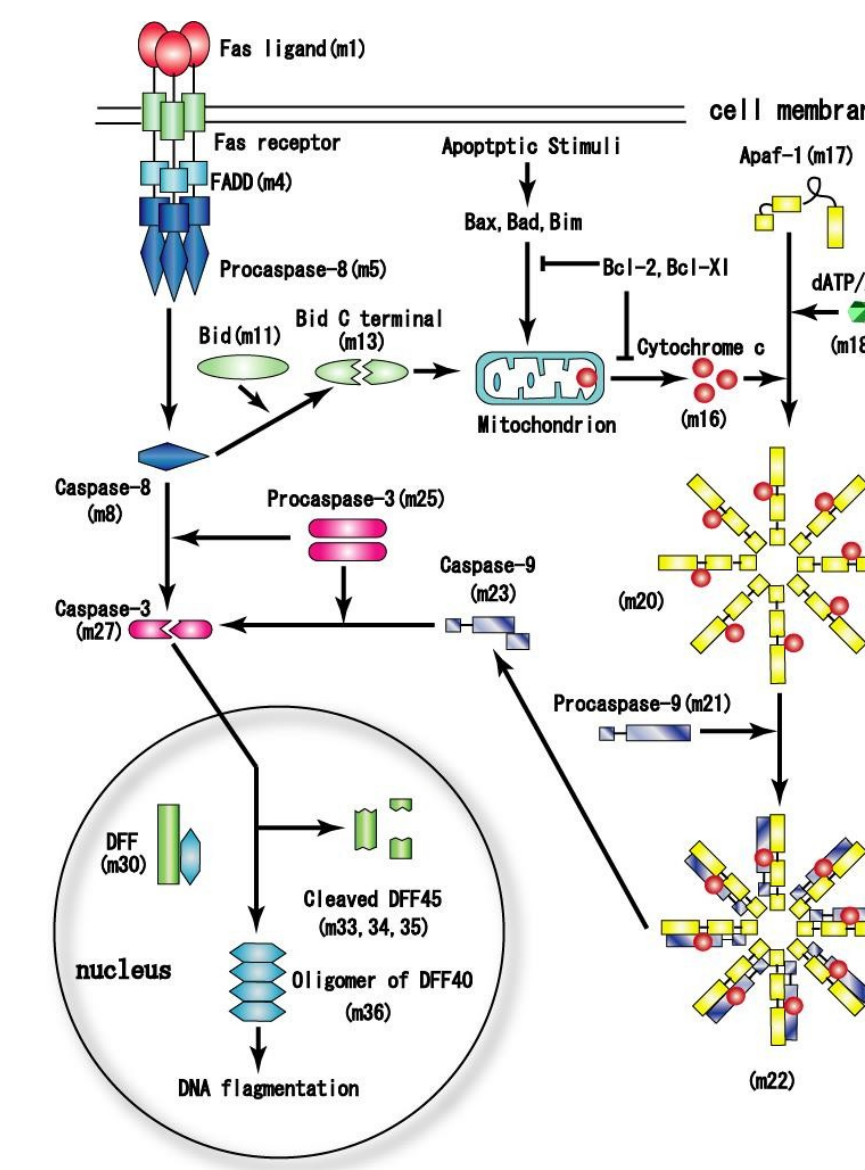
- non-ordinary
- k-bounded / unbounded
- live, reversible, BUT: how to prove?
- apparently unstructured
- over-exponential state space growth



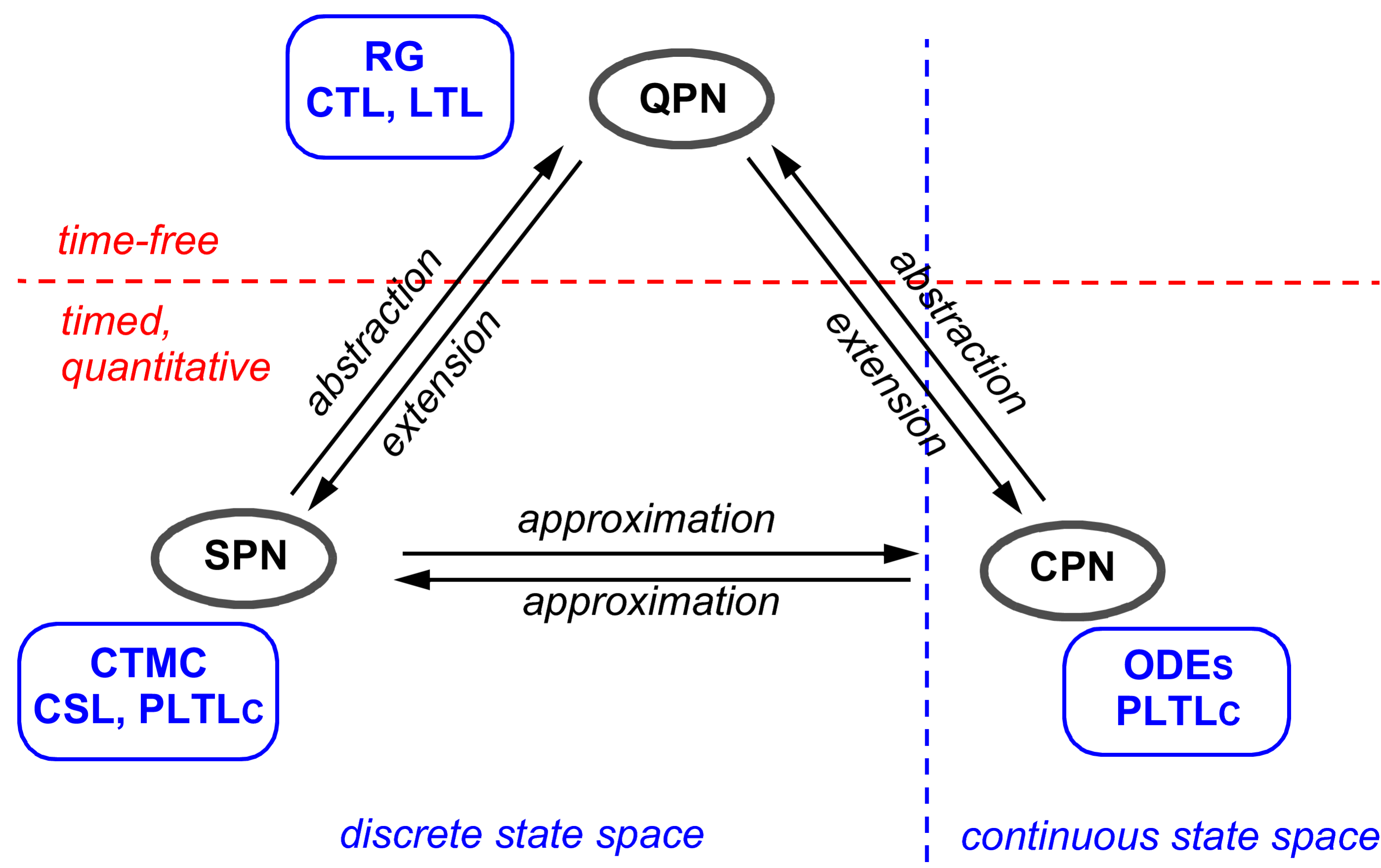
Production Cell [7]



Apoptosis in Mammalian Cells [8]



## Conceptual Framework



## Tool Kit

CHARLIE [23]

### Static – Net Structure

- Net classes
- Deadlock Trap Property
- Place/Transition invariants
- Dependent Sets

### Dynamic - Reachability graph

- Liveness, reversibility, dead states
- Explicit CTL/LTL model checker
- Path search
- Visualization
- Analysis of TPN
- Shortest/Longest paths

SNOOPY [5]

### Modelling/Animation

- Different Petri net formalism e.g. QPN, (X/G)SPN, CPN, GHPN, TPN
- Colored nets: QPN, (X/G)SPN, CPN
- Hierarchies, Coloring

### Analysis

- Stochastic Simulation Algorithm (SSA)
- Stiff/unstiff ODE solvers
- Fast adaptive uniformization (FAU)

### Import/Export

- SMBL
- Dedicated analysis tools (Charlie, MARCIE)

MARCIE [15]

### Qualitative Analysis of bounded nets

- Symbolic State Space representation with Interval Decision Diagrams (IDDs)
- Reversibility, liveness, dead states, SCCs
- CTL model checking

### Numerical Analysis of bounded (G)SPN

- IDD-based "on-the-fly" CTMC representation
- Transient/steady-state analysis (multi-threaded)
- CSL model checking (multi-threaded)

### Transient analysis of unbounded (G)SPN

- SSA (multi-threaded)
- FAU

## Outlook

- CSRL model checking
- Out-of-core techniques for numerical analysis
- Modular & distributed analysis techniques
- Model parametrization (constants, functions)
- Computational steering
- Colored GHPN
- Dedicated visualisation of biological networks

## Cooperations

- Gianfranco Balbo, Univ. Torino
- Rainer Breitling, Univ. Glasgow
- David Gilbert, Brunel Univ. London
- Jetty Kleijn, Univ. Leiden
- Kurt Lautenbach, Univ. Koblenz
- Wolfgang Marwan, Univ. Magdeburg
- Louchka Popova-Zeugmann, HU Berlin
- Sylvain Soliman, INRIA Paris

## References

### Analysis Methods / Tools

- [1] Tovchigrechko A: Ph.D. Thesis, BTU Cottbus, CS Dept. 2008
- [2] Heiner M, Gilbert D, Donaldson R: LNCS 2008
- [3] Heiner M, Schwarick M, Tovchigrechko A: PETRI NETS 2009
- [4] Schwarick M, Heiner M: CMSB 2009
- [5] Rohr C, Marwan W, Heiner M: Bioinformatics 2010
- [6] Schwarick M, Tovchigrechko A: TCS 2010
- [7] Liu F, Heiner M: BioPPN 2010
- [8] Herajy M, Heiner M: AWP 2010

### Applications

- [9] Heiner M, Deussen P, Spranger S: J. of AMT 1999
- [10] Heiner M, Koch I, Will J: J. BioSystems 2004
- [11] Koch I, Junker BH, Heiner M: Bioinformatics 2005
- [12] Popova-Zeugmann L, Heiner M, Koch I: FI 2005
- [13] Breitling R, Gilbert D, Heiner M, Orton R: Brief. Bioinformatics 2008
- [14] Heiner M, Lehrack S, Gilbert G, Marwan W: LNCS/LNBI 2009
- [15] Heiner M, Rohr C, Schwarick M, Streif S: CMSB 2010
- [16] Soliman S, Heiner M: PLoS ONE 2010

### Student's Thesis

- [17] Fieber M: Diploma Thesis, Snoopy, 07/2004
- [18] Noack A: Study Project, BDD CTL Model checking, 06/1999
- [19] Scheibler D: Diploma Thesis, Snoopy - CPN, 01/2006
- [20] Winder K: Diploma Thesis, Dependent Sets, 07/2006
- [21] Lehrack S: Diploma Thesis, Snoopy - SPN, 11/2007
- [22] Fischer A: Diploma Thesis, Charlie - TPN, 10/2009
- [23] Franzke A: Diploma Thesis, Charlie 2.0, 12/2009
- [24] Probst M: Master Thesis, Marcie - Out-of-Core, 02/2011