

Advanced Systems Engineering

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Complex ICT-Powered Systems

Agriculture **Smart Cities**
Food Manu. **eHealth** **Smart Grid**
Transport **Home Automation**



Embedded Systems

WWW



Mobile Services

WWW



Cloud



Activities on SoS (partial list)

CISS

- Regional Competence Center (10 years)

InfinIT

- National Innovation Network on ICT
- E.g. Safety Critical Systems, MDD & OO, Smart Grid, Intelligent Buildings, Green ICT.

ITOS

- National 4-year project on System Engineering for Complex Systems.
- Danish Industry + 30 companies + DTU/AAU.
- A number of Masterclasses and State-of-the-Art Workshops

ENCOURAGE (ARTEMIS), INTrePID, TOTALFlex

- Optimization of generation, storage and consumption of energy
- Infrastructure

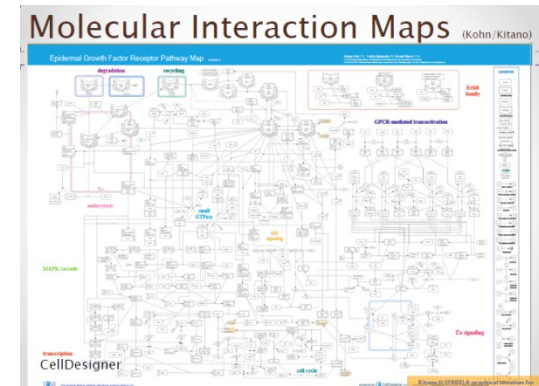
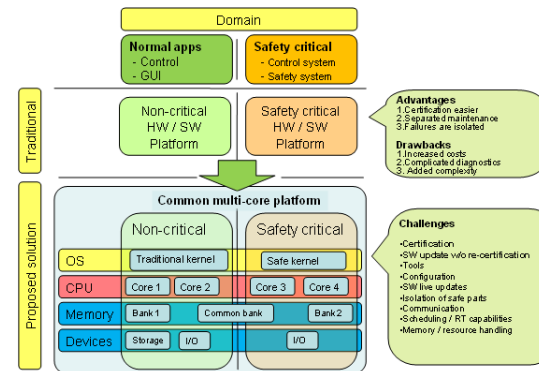
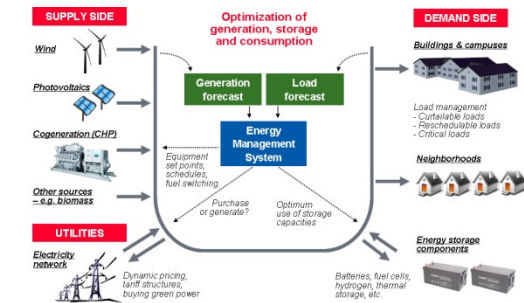
SENSATION (FET ProActive)

- Minimizing Energy Consumption of ICT to the Limit.

MBAT, RECOMP, CRAFTER (ARTEMIS)

- Model-based Analysis and Test for Complex Systems

Biological Systems



SoS Features (Challenges)

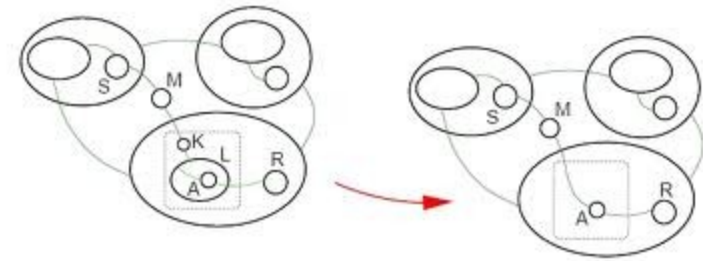
- **DISTRIBUTED:**
 - Subsystems have their own objectives
 - Decentral control, yet specification with global constraints
 - Dataintensive
- **COLLABORATIVE**
 - global behaviour emerges from the interactions between the subsystems;
- **LARGE**-scale and **MULTI**-scale
- **ADAPTIVE**
 - adapt to continuously evolving environment
- **OPEN**
 - the structure of the whole system is not fixed a priori, might join or leave the system
- **QUANTITATIVE CONSTRAINTS**
 - e.g. timing and energy constraints
- **SECURITY**



Directions (adaptivity, openness)

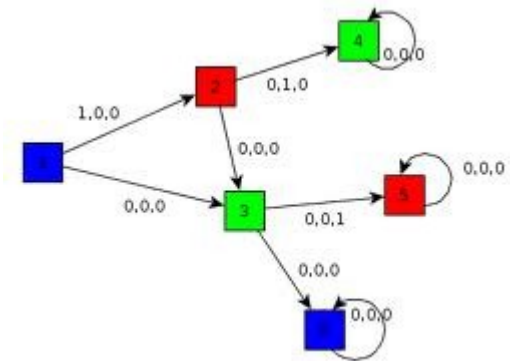
Dynamic Behavioural Models

- Mobility, aggregation & decomposition of objects. Hierarchy of objects
- Dynamic creation of objects
- Pi-Calculus, Bigraphs, Ambient Calculus,
- Evidence in Biology.



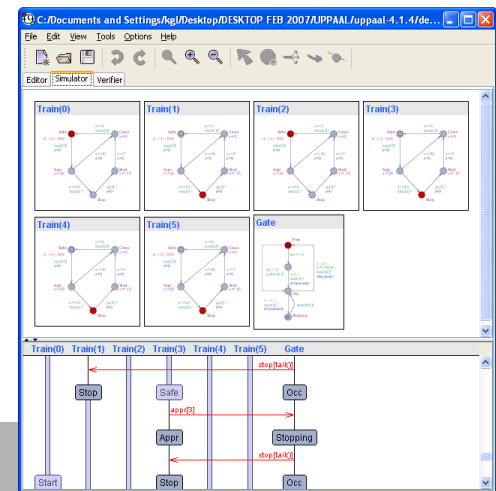
Game Theory

- Subsystems are players with behaviour being strategies.
- Collaborative = Non-zero Sum Games
- Correctness \square Synthesis
- Optimality \square Multiple Objectives, Equilibria
- Several very strong theoretical research groups!
- Indication of potential in previous projects (Quasimodo)



Tools & Algorithms

- Synthesis & Model Checking Algorithms
- Distributed & Multicore Implementations
- Model Checking, Simulation
 - \square Statistical Model Checking, Learning.



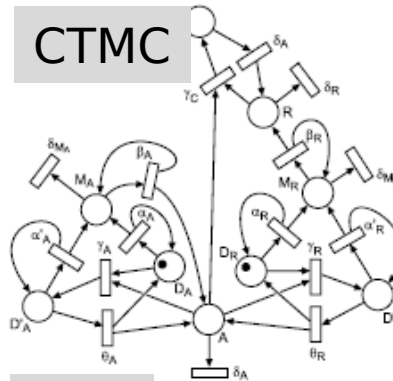
Directions (multiple scales)

Need for relating radically different models:

- Stochastic models (faithful, detailed, large).
- Deterministic continuous fluid models (underapproximate, manageable)
- Deterministic, discrete models (overapproximate, scalable)

New methods for analysis

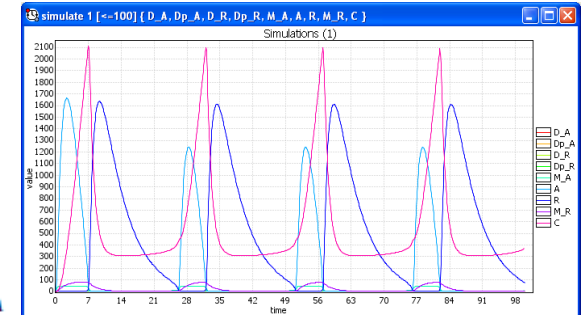
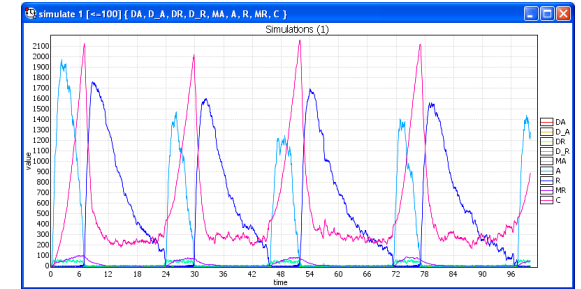
- Simulation & verification
- Composition, Abstraction
- Rich Interfaces
- Metrics



ODE

$$\begin{aligned}
 dD_A/dt &= \theta_A D'_A - \gamma_A D_A A \\
 dD_R/dt &= \theta_R D'_R - \gamma_R D_R A \\
 dD'_A/dt &= \gamma_A D_A A - \theta_A D'_A \\
 dD'_R/dt &= \gamma_R D_R A - \theta_R D'_R \\
 dM_A/dt &= \alpha'_A D'_A + \alpha_A D_A - \delta_{M_A} M_A \\
 dM_R/dt &= \alpha'_R D'_R + \alpha_R D_R - \delta_{M_R} M_R \\
 dA/dt &= \beta_A M_A + \theta_A D'_A + \theta_R D'_R \\
 &\quad - A(\gamma_A D_A + \gamma_R D_R + \gamma_C R + \delta_A) \\
 dR/dt &= \beta_R M_R - \gamma_C A R + \delta_A C - \delta_R R \\
 dC/dt &= \gamma_C A R - \delta_A C
 \end{aligned}$$

Timed Automata



Periods

