L02- The Paradigm of PNs

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Outline

I. Complex Systems Specification and Modelling
   Capabilities to be developed

II. Modular Approaches
   I. CS oriented models
   II. Synchronous Synchronization of models
   III. RAS oriented models

III. Hierarchical Approaches
   I. Models with Static High Level Structure
   II. Models with Dynamic High Level Structure
   III. Hierarchical Constructive Methodologies

IV. Open problems
Petri nets were developed in the early 1960s by C.A. Petri in his Ph.D. dissertation

The Theory of the **Inflationary Petri Net Universe**

A **Tower of Babel** where live many different Petri Net languages induced for applications, for managing
- Continuous/Hybrid systems
- Timed systems
- High-level information or tasks of the system
- Variable Parameter Systems

This is not inherently bad.

**My initial view is:**

Given a System to be studied or designed,
- we are not interested in **THE** model
- we are interested in **A** model to obtain answers

**...to obtain answers**

- Good descriptive power
- Only the necessary details
- Theoretical results for reasoning
- Software tools available ....
… Modelling Complex Systems

- **Complex Systems – Reasons for complexity**
  - **Size of the System**
    - Interconnection Network of a Multicomputer System – 64k Routing Nodes + Message Passing Channels
  - **Intricated (Dynamically) Structured System** composed by non-independent subsystems
    - National Railway Control System
    - Hierarchical Control System of a Manufacturing Plant
  - **Multi-Featured Systems**
    - Too many features to be considered at once – Biological systems

- **Models to cope the complexity of a system**
  - **Systems of Great Dimensions**
    - Parameterised models
  - **Abstraction Mechanisms:**
    - Symmetries (regular interconnection networks),
    - Populated Models (processes managed by an operating system),
    - Approximated Models (parameters of the data-stream in Internet instead of the real data-stream)
  - T.B.D. (…)
Models to cope the complexity of a system (cont.)

- Intricated (Dynamically) Structured Systems composed by non-independent subsystems
  - Non-Flat Models – High-Level Model Structuring Concepts
  - High Level Structural Issues
    - Active components – **Functional entities**
    - Passive components – **System Resources**
    - Communication/Synchronization between components
      - Synchronous (rendez-vous)
      - Asynchronous (message passing)
    - Hierarchical relations between components
      - 1-Level – Modular composition
      - Multilevel – Hierarchical composition
    - Static vs. Dynamic structure

Multi-Featured Systems

- Feature Oriented Models – Feature Abstraction
  - Resource Allocation Systems’ (RAS) oriented models
  - Communicating Systems’ (CS) oriented models
  - Performance oriented models
  - Scheduling oriented models
- Interrelationships between Featured Models of a given system
II. Modular approaches

On the basic modules of the modular approaches

a. Place/Transition Nets

A Place/Transition Net is a 4-tuple

\[ N = (P, T, F, W), \]

where

- \( P = \{p_1, p_2, \ldots, p_m\} \) is a finite set of places
- \( T = \{t_1, t_2, \ldots, t_n\} \) is a finite set of transitions
- \( F \subseteq (P \times T) \cup (T \times P) \) is a set of arcs
- \( W: F \rightarrow \{1, 2, 3, \ldots\} \) is a weighting function
- \( P \cap T = \emptyset \) and \( P \cup T \neq \emptyset \)
a. Place/Transition Nets

A philosophers problem
A philosophers problem

b. Coloured Petri Nets

Another philosophers problem

Credits: Kurt Jensen, Aarhus University, Denmark
II. Modular approaches

Communicating Systems’ (CS) oriented models

A Deterministic System of Sequential Processes (DSSP) is a P/T net system composed of:

- A set of Sequential Processes
  - 1-safe strongly connected State Machines \((N_i, M_{0i})\)
- A set of buffers
  - Buffers are output-private
  - Buffers respect internal choices of the SP
    - Reisig (1982): Buffers I/O private; no weights
    - Souissi et al. (1988): Buffers I/O private
II. Modular approaches

Synchronous Synchronization of models
A **Synchronized Automata** is a P/T net system composed of:

- A set of **Sequential Processes**
  1-safe strongly connected State Machines \((N_i, M_{0i})\)

- Classes of **private transitions occurring simultaneously** in the owner Sequential Processes
II. Modular approaches

Resource Allocation Systems’ (RAS) oriented models

A S³PR net system:
- a set of strongly connected state machines
  - one for each type of part – Process Plans
  - two kind of places – Idle State + Processing States
  - a structural termination property: all circuits contain the idle place – Production sequences
RAS oriented models

- a set of resource places
  - each resource place – **Type of resources**
  - initial marking of a resource place – **Number of identical copies of a type of resource**;
  - only one copy of only one resource type per part in a state

- **an admissible initial marking**
- composition of production plans with resources via fusion of resource places
III. Hierarchical Approaches

Models with Static High Level Structure

Hierarchical Coloured Petri Nets:

- **Static Structure** defined through the declared hierarchy of pages
- These models correspond to a *methodology* to construct understable and manageable models of complex systems
- There exist equivalence notions with low level models – “Unfoldings”, etc.

Another examples: “Siesta” Nets
III. Hierarchical Approaches

Models with Dynamic High Level Structure

The **Nets within Nets** paradigm:

- **System Net** – High Level Static Structure
- **Object Nets** (tokens) – **Dynamic part** of the system structure
- Multilevel hierarchy is allowed
- Synchronization between different levels is allowed
Nets within Nets

Credits: Rüdiger Valk, Hamburg University, Germany

III. Hierarchical Approaches

Hierarchical Constructive Methodologies
Hierarchical Constructive Methodologies

The Refinement/Abstraction operations:

- Methodology for the construction of models – Close to the programming methodologies
- Refinement/Abstraction two sides of the same coin
- The toolbox – A set of Rules
  - Local conditions for the substitution operation
  - Rules defined to maintain certain equivalence notions between the two models implied in the rule
  - In the final model there is no trace of the hierarchy
  - The construction is assisted by heuristics

IV. Open problems

- Revisiting High Level Structural Components (Generalizing known modular models)
  - Active components – Beyond Sequential Processes
  - Passive components – Beyond the pattern Request-Use-Release
  - Communication/Synchronization
    - Beyond “Buffers”: Communication Channels
    - Beyond “Rendez-vous”: Synchronization protocols
  - Hierarchical relations between components
    - 1-Level – Beyond fusion of places or transitions
    - Multilevel – OPEN!
IV. Open problems

- Defining the structure of the High Level Structural Components (Methodologies + Systems with a Dynamic High Level Structure)
  - Methodologies for the hierarchical construction of models
    - Beyond the synthesis of free choice nets
    - Feature oriented toolbox of Refinement/Abstraction rules
    - Methodologies for the construction - Heuristics
  - Evaluation of the Nets within Nets Paradigm

- Defining bridges/relations between feature oriented models of a same given system
  - RAS and CS views of a system –
    - Combination of views
    - Propagated constrains between different views
  - The timed view in the Nets within Nets Paradigm
IV. Open problems

- Modular Analysis Techniques of Modular Models (Incremental analysis techniques)

Bibliography
