Petri Nets

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Petri nets

• Modeling language
  ▪ concurrent and distributed SW systems
  ▪ reactive systems (asynchronous events)

• Notations: graphical, mathematical

• Many variants and extensions
  ▪ Basic (ordinary)
  ▪ Colored (CPN)
  ▪ Hierarchical nets
Basic elements

- Places
- Transitions
- Arcs
- Tokens
Semantics

• Marking
  - Function $M : P \rightarrow N$

• Transitions
  - Enabled: when input places contain enough tokens
  - Firing (execution)
    • Removing tokens from input places
    • Adding tokens to output places
Examples

- Conflicting transitions
- Independent transitions
- Synchronization
Petri net is a tuple \((P, T, A, w, M_0)\), where:

\[ A \subseteq (P \times T) \cup (T \times P) \]

\[ P \cap T = \emptyset \] \quad \text{(disjunct)}

\[ w: A \rightarrow N \text{ is a weight function} \]

\[ M_0: P \rightarrow N \text{ is the initial marking} \]

Reachability graph \( R \)

\[ M_0 \in R \]

\[ M \in R \land t \in T \text{ enabled in } M \text{ s.t. } M \xrightarrow{t} M' \Rightarrow M' \in R \]
Example: dining philosophers

- Two philosophers
- Two shared forks
Properties

- Reachability of $M$
  - $\exists$ sequence of transitions from $M_0$ to $M$
- Reachable markings $R(M)$
- Coverability of $M$
  - $\exists M' \in R(M_0)$ such that $\forall p \cdot M'(p) \geq M(p)$
- Applications: verification, simulation, analysis
Variants

- Ordinary Petri net
  - every arc has the weight 1

- State machine
  - every transition has exactly one input place and one output place

- Colored Petri Nets
Colored Petri Nets (CPN)

• Support for data types and manipulation

• Multiple types of tokens (colors)
  ▪ data type = set of values \approx \text{set of colors}
  ▪ token value \approx \text{token color}

• New elements
  ▪ Places: color sets (allowed token types)
  ▪ Transitions: guard conditions (enabling)
  ▪ Arcs: arc expressions (transferring values)
Example
- Distributed storage system with a very simple protocol for synchronization
  - Entities: client, server, data storage

Applications
- Communication protocols
- Distributed algorithms
- Control for embedded systems
Tools

- Popular editors for creating diagrams
  - [https://app.diagrams.net/](https://app.diagrams.net/) (former draw.io)

- PetriDotNet

- CPN Tools
  - [http://cpntools.org/](http://cpntools.org/)
  - [http://cpntools.org/download](http://cpntools.org/download)

- PIPE 2
Literature

- Basic Petri Nets
    - Further details and references to various literature

- Colored Petri Nets