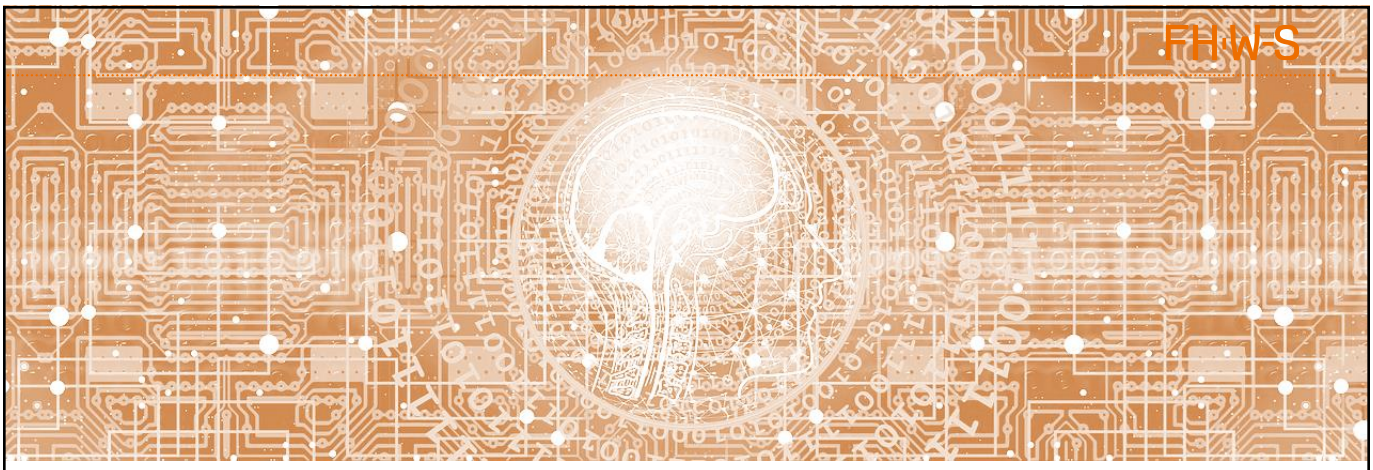

Embedded Systems and Field Buses

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Agenda

- Fundamentals
- Structure of Embedded Systems
- Behavior of Embedded Systems
- Design of Embedded Systems
- Communication
- Real-time
- Collaborative Embedded Systems

FH·W-S

Behavior of Embedded Systems

Part A: Petri Nets

Group Discussion

Why is Structure not enough?

Formal Languages

Behavior is typically described using formal languages.

The use of formal languages allows (among others)

- Formal **Proof of Concept**
- **Simulation**
- Analyses (e.g. **Deadlock** and **Lifelock** detection, finding an **Equilibrium**)
- **Verification**
- Test Case Generation
- …

Automata Theory

Finite State Machines

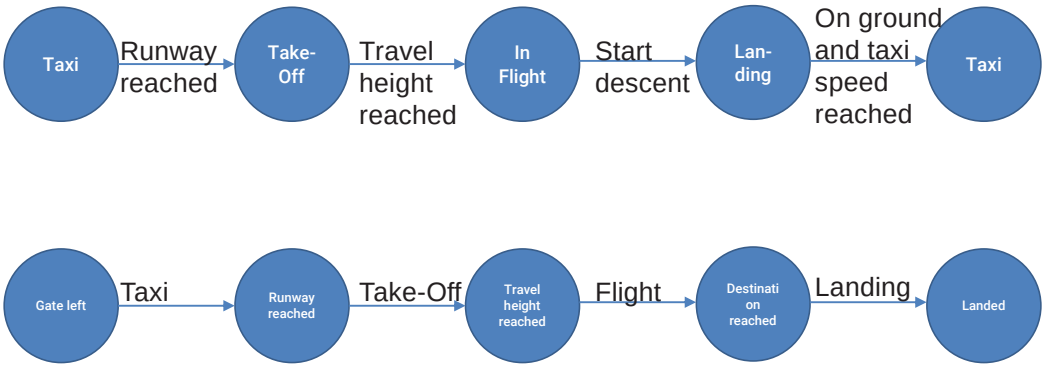
Automata typically have
- A **formal** representation
- A **graphical** representation

Automata foremost consist of
- **States**
- **Transitions**

Further concepts include:
- Start/initial states
- Final/accepting states
- Events and Conditions

Depending on the language the focus is either on
- the **States**
- the **Transitions**
- or **Both**

State vs Transition



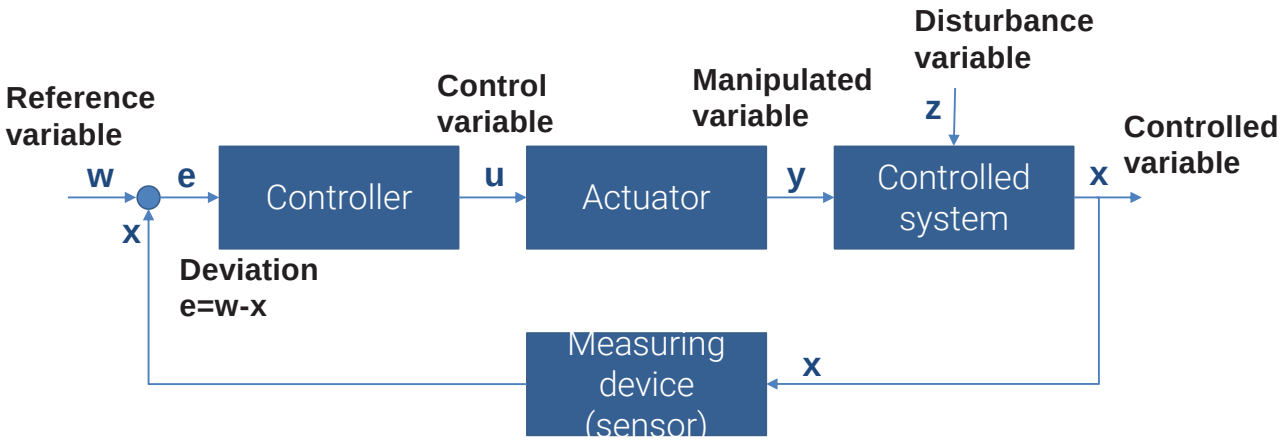
Group Discussion

What is an Alphabet?

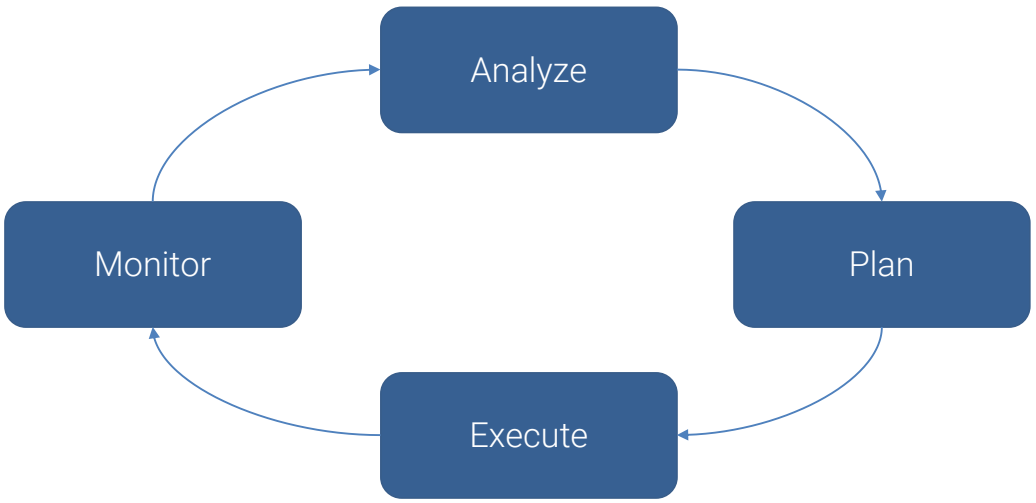
What are basic Operators?

Remember
Control- and MAPE-Loops

Control Loop



MAPE-Loop



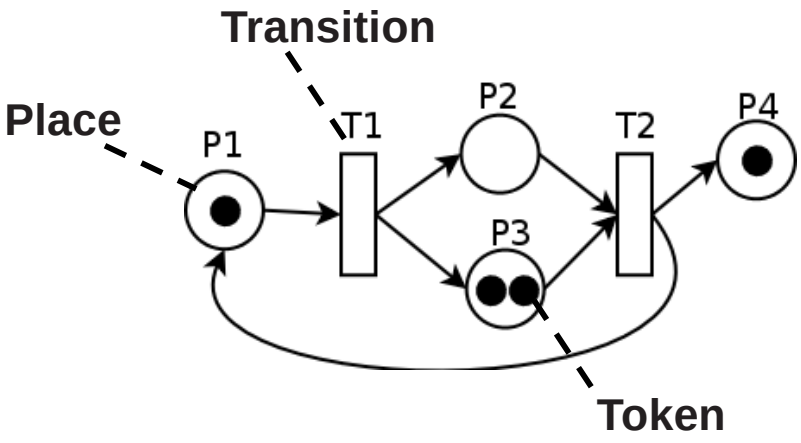
Petri Nets

Online-Materials

Introduction videos to Petri Nets can be found at:

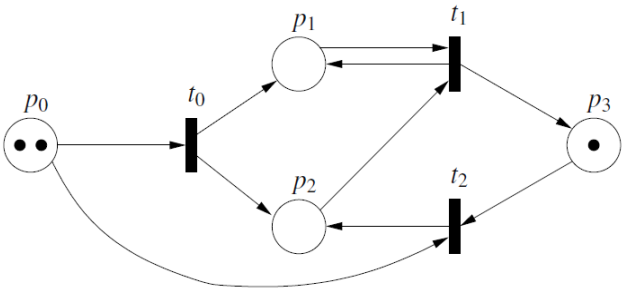
https://youtu.be/GCsVxWh995o
https://youtu.be/WGSAi9-QUwk
https://youtu.be/1IPOlE0PvQY

Elements



Petri nets

Is transition t_2 of the petri net shown below enabled? (Capacity of places is ∞)
What is the marking after t_2 fires?



Exercise

Model a Traffic Light using Petri Nets

Analysis

Terms:

A transition is dead, if it is not enabled in any marking.

A transition t is potentially fireable, when there is at least one marking reachable, which enables t.

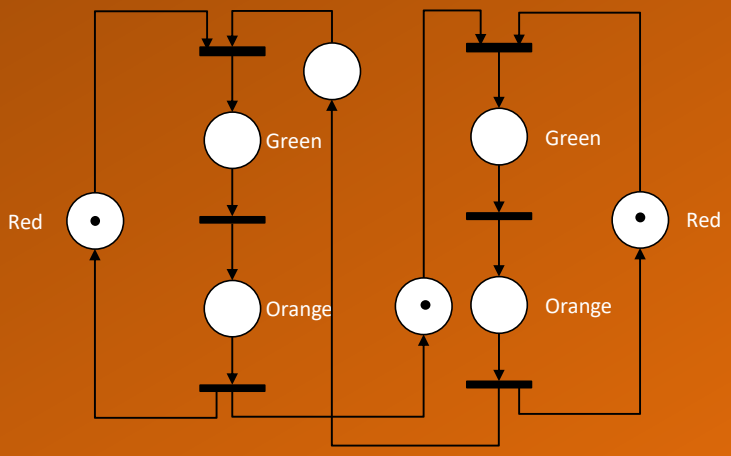
A petri net is dead, if no transition is able to fire in a given marking.

A petri net is quasi alive, if not dead under any future marking.

A petri net is alive, when all transitions are potentially fireable for all future markings.

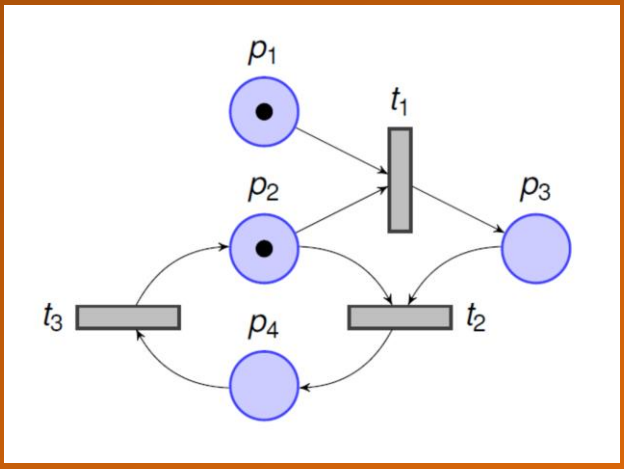
Exercise

Quasi alive or alive?



Exercise

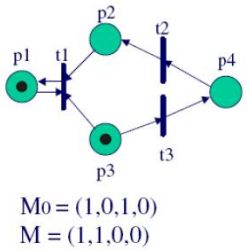
Quasi alive or alive?

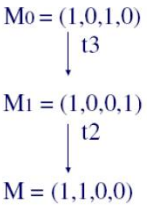


Reachability Graph

Firing sequence for a petri net G and initial marking M0 is a sequence of transitions $t_0, \dots, t_n$, such that $M_0 \xrightarrow[G,t_0]{} M_1 \xrightarrow[G,t_1]{} \dots \xrightarrow[G,t_n]{} M_n$

Reachability graph: The reachability graph of G is the transition relation $\xrightarrow[G]{}$ restricted to its reachable markings $R(G)$. It is the state space of the net.

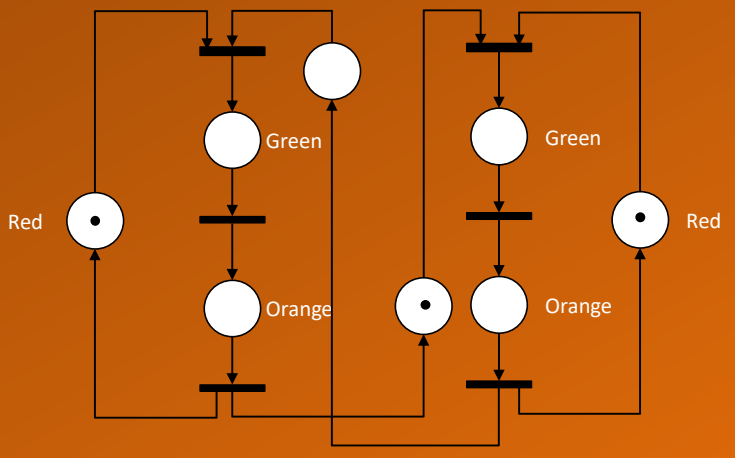




Nassar, K., & Casavant, A. (2008). Analysis of timed Petri nets for reachability in construction applications. *Journal of Civil Engineering and Management*, *14*(3), 189-198.

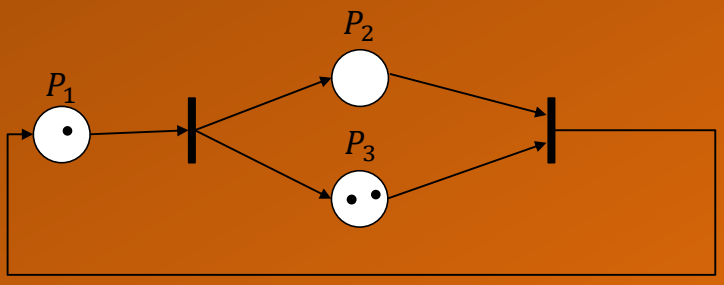
Exercise

Draw the Reachability Graph



Exercise

Draw the Reachability Graph



Group Discussion

Why are Petri Nets commonly suggested for analysing embedded systems?

Where are Limitations of Petri Nets?

Exercise

For home:
Google the Dining Philosophers Problem and Model it with Petri Nets

Questions for Self-Assessment

What are the basic concepts of automata theory?
What is a petri net?
When does a petri net fire?
Are petri nets deterministic?
When is a petri net dead, alive, quasi alive?
What is a reachability graph?
What are shortcomings of petri nets?
Why are petri nets often suggested for modelling embedded systems?

Literature

[Hopcroft et al. 2006] Introduction to Automata Theory, Languages, and Computation. 3rd Edition, Pearson Education, 2006.

[Reisig 1991] Reisig, W.: Petri Nets and Algebraic Specifications. In: Theoretical Computer Science, 80(1), 1991, pp. 1-34.