

The Use of Fuzzy Coloured Petri Nets for Modelling and Simulation in Manufacturing

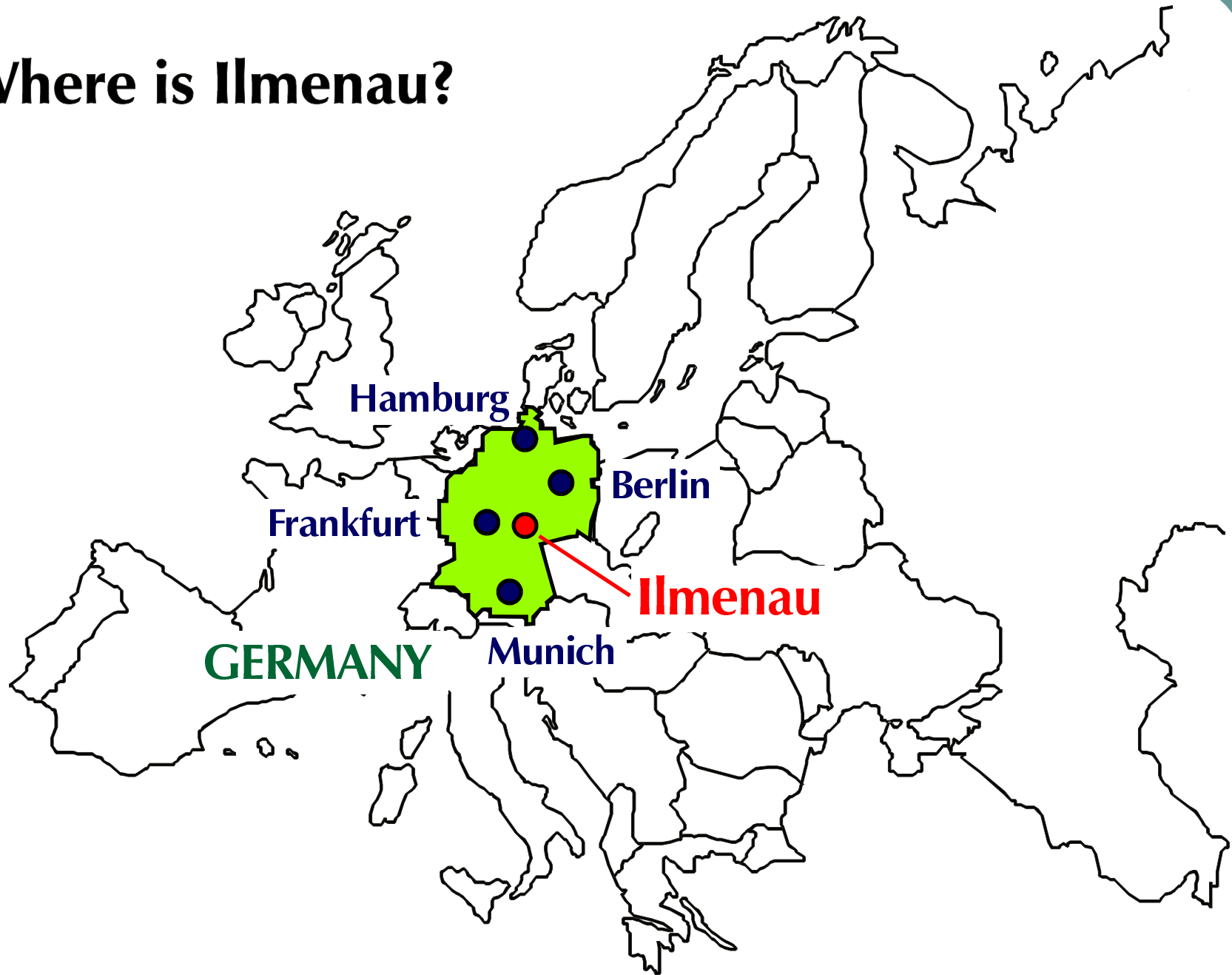
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Where is Ilmenau?

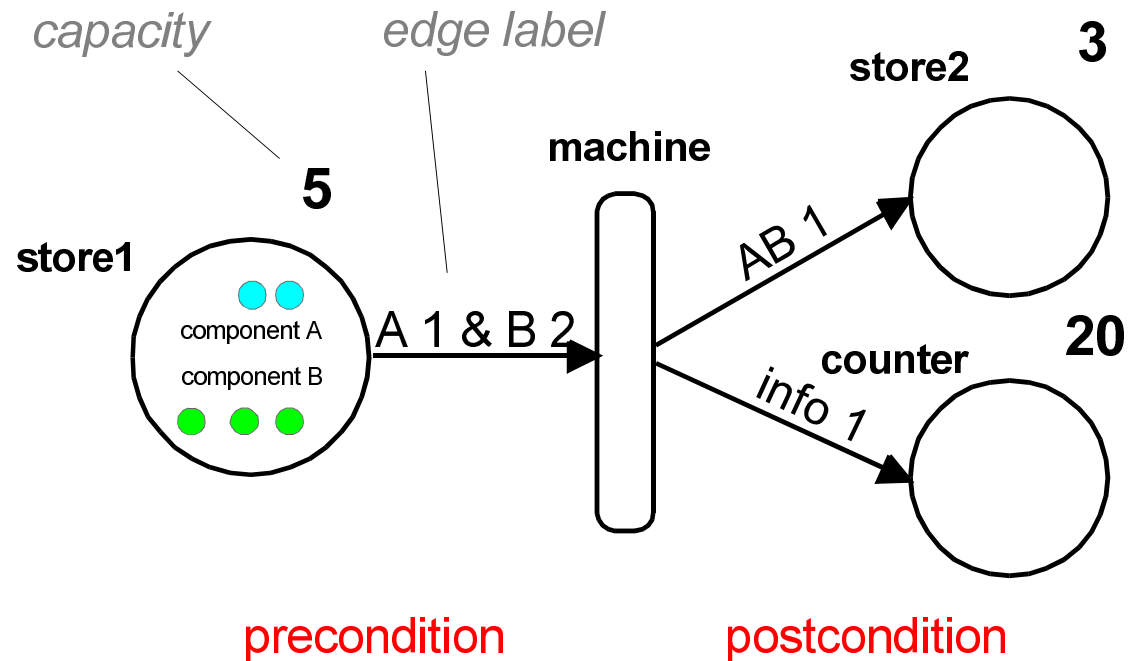


The Use of Fuzzy Coloured Petri Nets for Modelling and Simulation in Manufacturing




Topics

-  Introduction of Fuzzy Coloured Petri Nets (FCPN)
-  Modelling of manufacturing with FCPN
-  Example model of manufacturing
-  Summary and future plans




Basic Elements of Coloured Petri Nets (CPN)



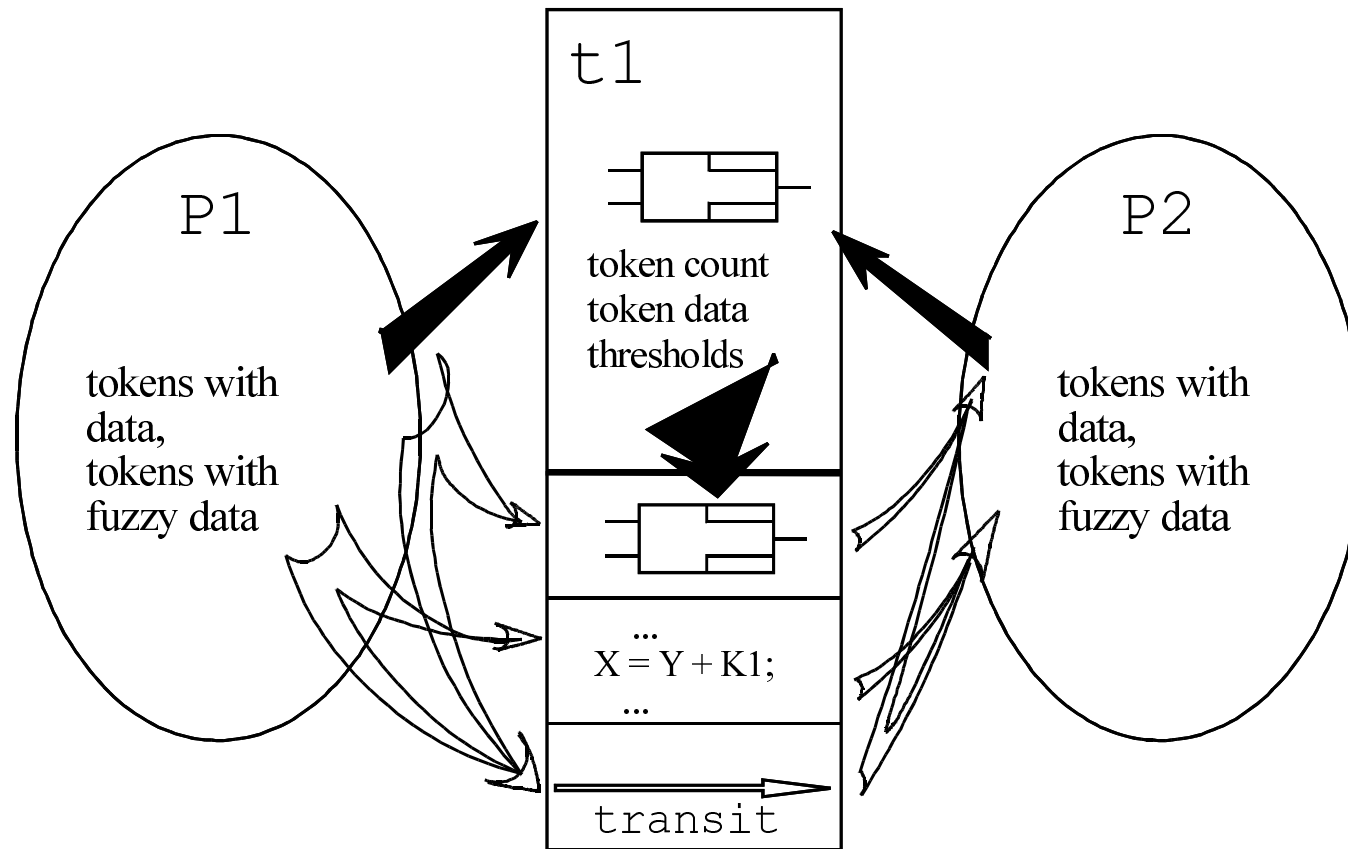
Known Approaches to Fuzzy-Attributed Petri Nets

-  Fuzzy tokens → *non-discrete events*
-  Fuzzy pre- and postarcs → *dynamical structures*
-  Fuzzy transition behavior:
 - a)** Fuzzy firing rule → *hard analysing*
 - b)** Fuzzy conflict solving → *good analysing*

Fuzzy Coloured Petri Nets (FCPN)

-  Petri nets → *known methods of analysing and simulating*
-  Coloured Petri nets → *compact structures*
-  Fuzzy logic → *fuzzy values and decisions*

The Fuzzy-Transition







Fuzzy Transition: Firing Conditions

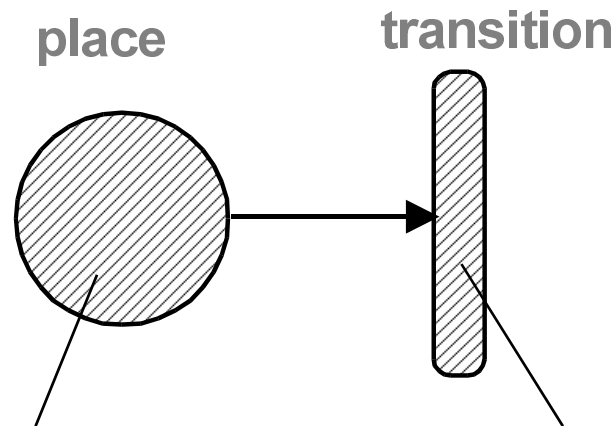
- 🖱️ Preplace token count, per colour
- 🖱️ Postplace token count, per colour
- 🖱️ Comparison with threshold value
- 🖱️ Fuzzy data values of individual tokens
- **Non-fuzzy firing rule**

Fuzzy Transition:

Fuzzy Effected Firing Results

-  Postplace token count, per colour
-  Fuzzy data values of individual tokens
-  Data values of individual tokens
-  Token selection in conflict case

Additional Functions in Fuzzy Coloured Petri Nets



w_d : data function
 w_y : output function
 w_{ap} : action function






w_x : condition function
 w_t : time function
 w_{at} : action function
 w_{ft} : fuzzy condition function

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Topics

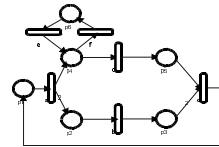
- 🖱 Introduction of Fuzzy Coloured Petri Nets (FCPN)
- 🖱 **Modelling of manufacturing with FCPN**
- 🖱 Example model of manufacturing
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Problems in Small-Lot and Single-Piece Manufacturing

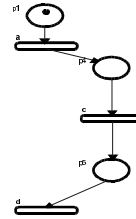
-  Many different sequences
-  Great flexibility required
-  Large amount of preparation times
-  Difficult control of manufacturing
-  Lack of algorithms for optimizing

Modelling in Manufacturing

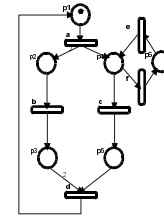
topological situation



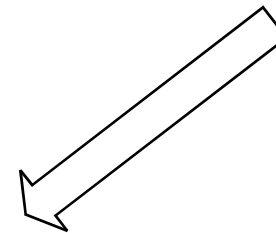
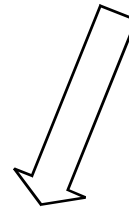
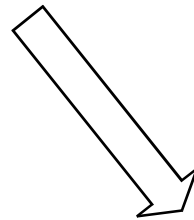
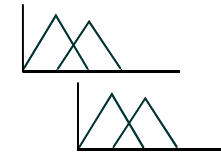
workflow



scheduling



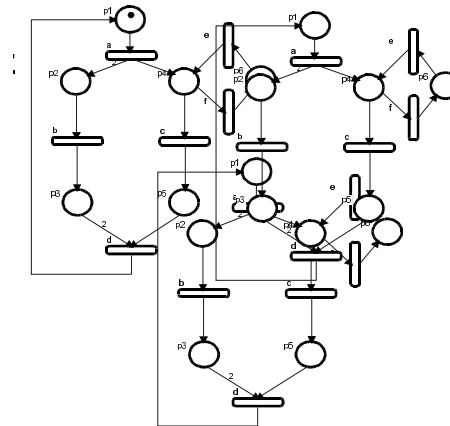
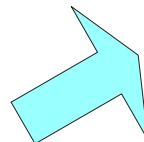
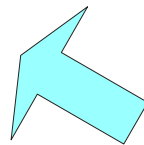
fuzzy model



simulation







feedback






integrated net





Goals of Modelling of Manufacturing

-  Optimization (multiple goals)
-  Simulation for preview
-  Flexible control of manufacturing
-  Short and long term planning

Why Fuzzy Logic in Modelling of Manufacturing?





-  Simple statements
-  Reduced simulation times
-  Inclusion of not fully known aspects

Fuzzy Aspects in Manufacturing

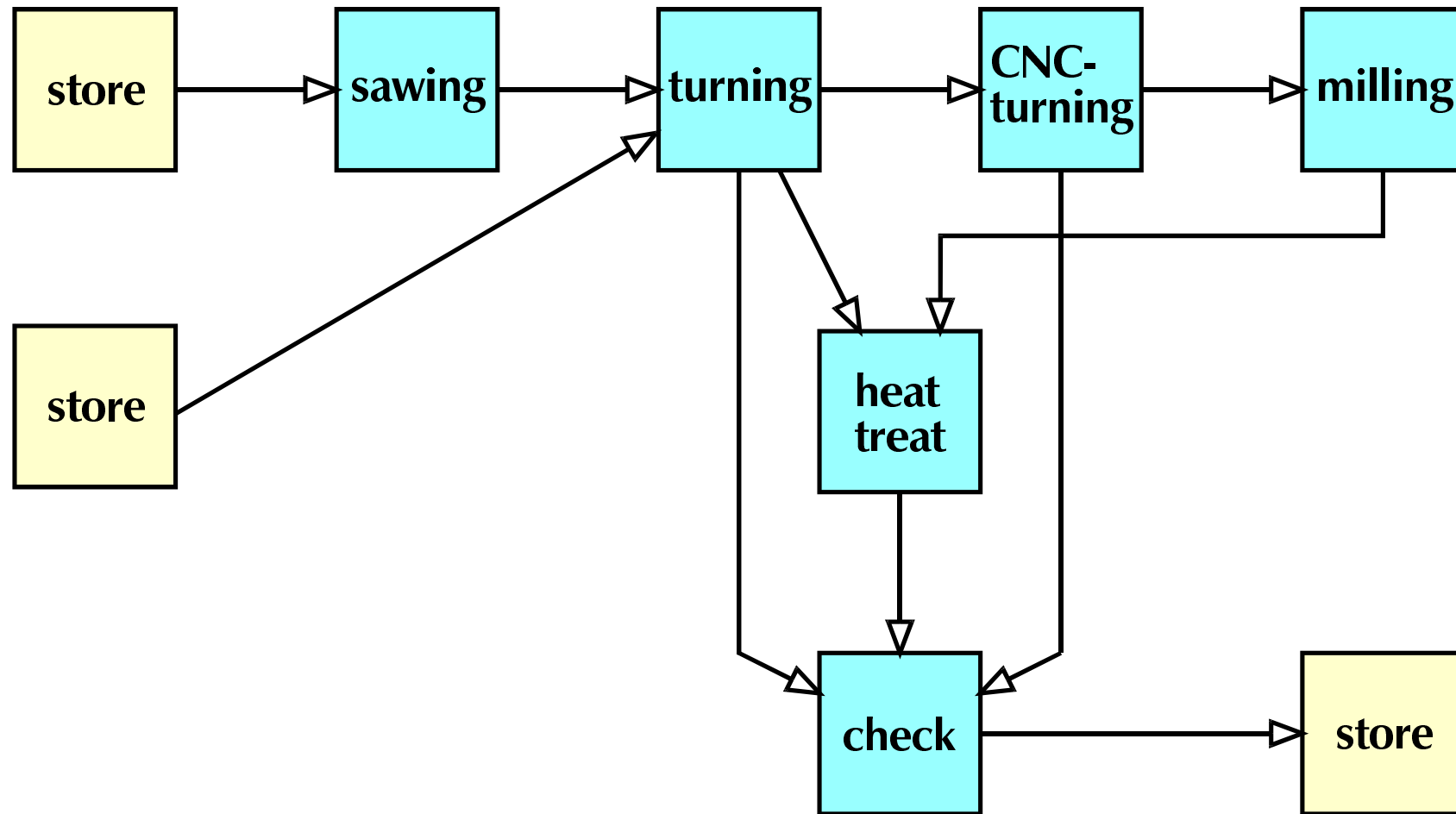
-  Values (time, count, speed ...)
-  Thresholds (quality, capacity ...)
-  Sequences (tasks, machine types ...)
-  Goals (efficiency, total times ...)

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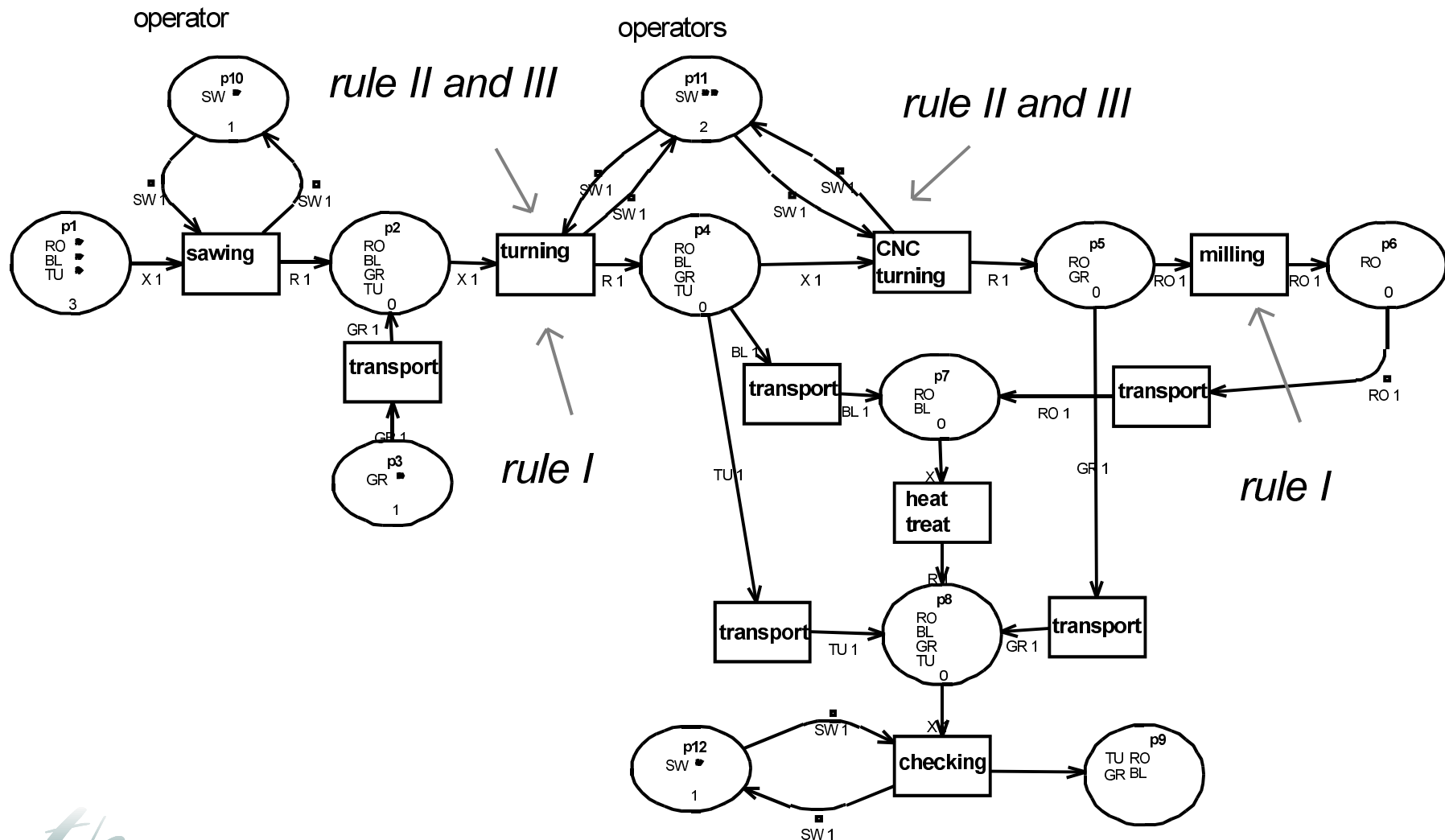
Topics

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Example: Technological Process



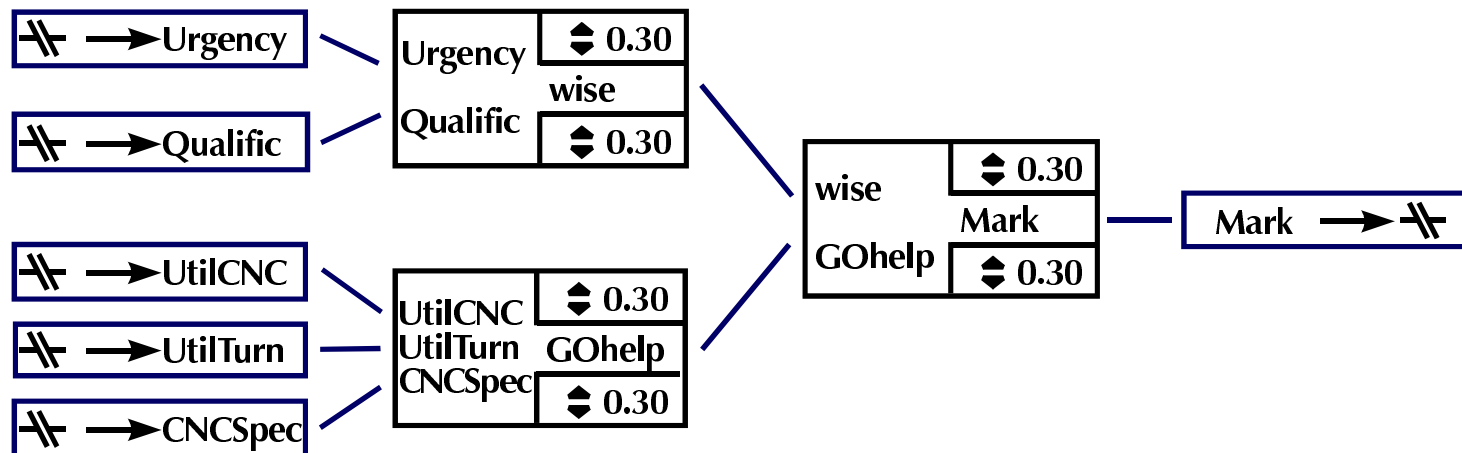
Example Petri Net



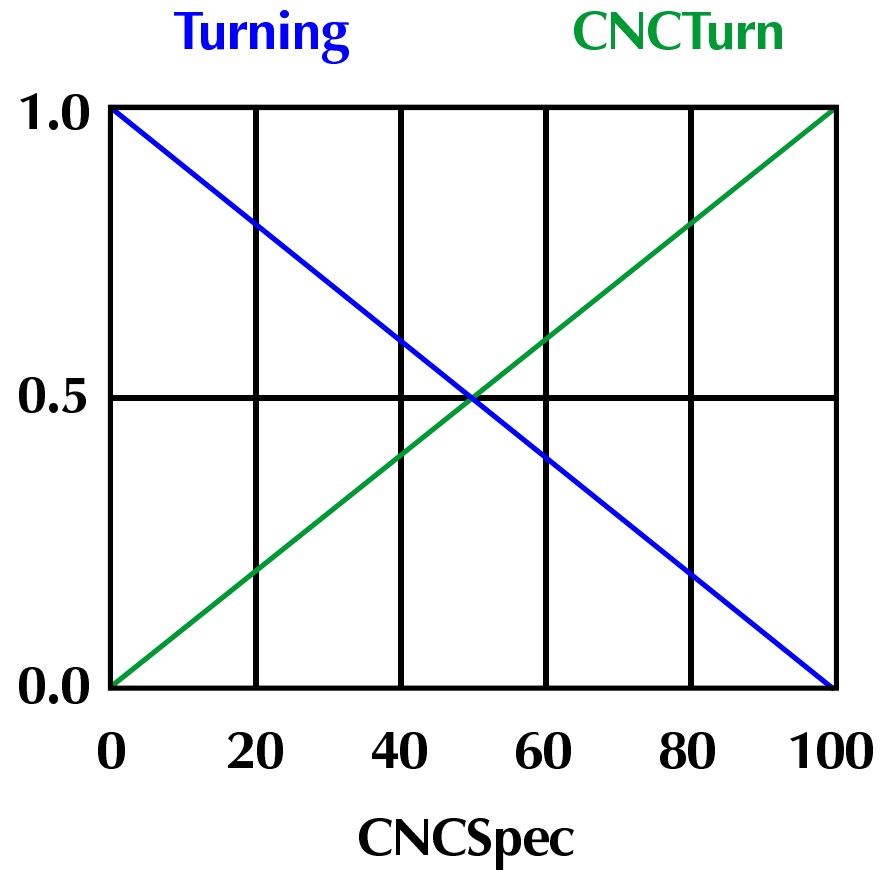
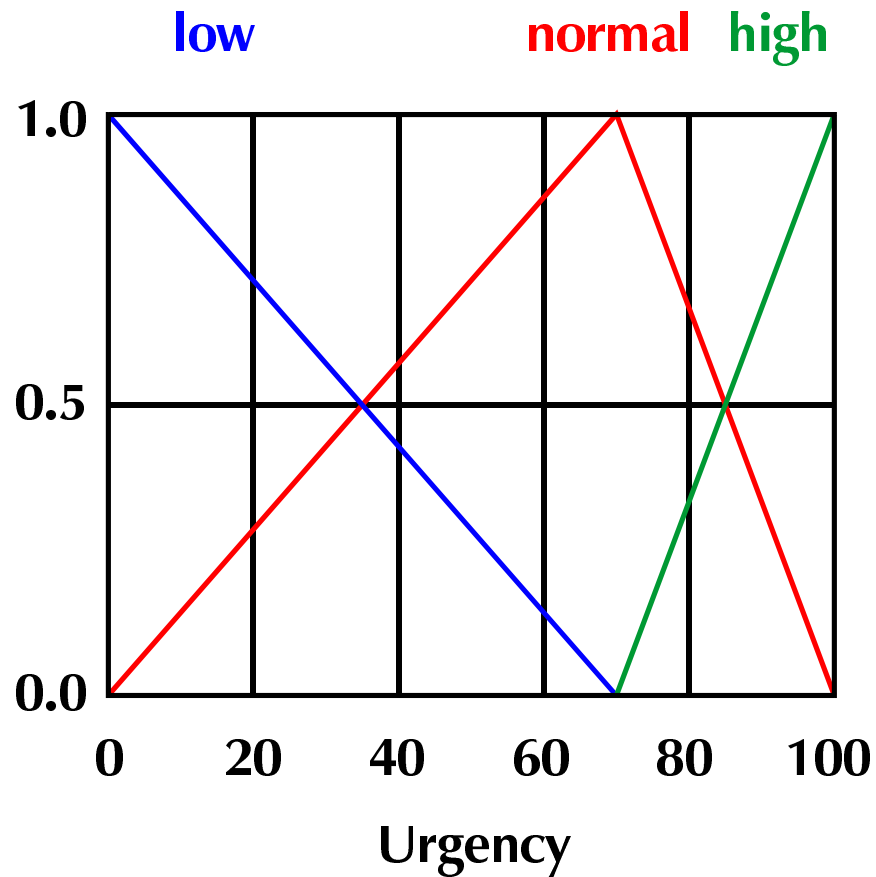
Example: Fuzzy Rules

- Rule I:** **If** a job is very urgent
 then it has to be worked as soon as possible.
- Rule II:** **If** there are many jobs for turning
 and if the operator for CNC-turning has few jobs
 then he can help at turning.
- Rule III:** **The more** urgent a job
 the higher the qualification of the operator has to be.

Example: Linguistic Variables and Rule Blocks



Example: Membership Functions



Example: Combinations for Linguistic Variable "wise"

		Qualification		
		low	normal	high
Urgency	low			low
	normal			
	high	low		

wise = low





		Qualification		
		low	normal	high
Urgency	low	low		
	normal	low	low	
	high			

wise = normal





		Qualification		
		low	normal	high
Urgency	low		high	
	normal			high
	high		high	high

wise = high

Summary

-  Software-interpreted Petri nets are useful to model complicated systems.
-  A Fuzzy extension to Coloured Petri nets has been introduced.
-  These **Fuzzy Coloured Petri Nets** are useful to model manufacturing systems.
-  A **FCPN** development tool is under preparation.

Future Plans

-  Methods for evaluation and simulation
-  Migration to other application fields
-  Model libraries for particular application fields
-  Further development of the FCPN tool