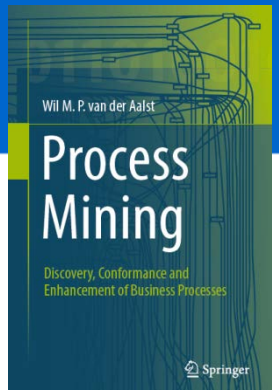
*Process Mining: Data Science in Action*

# Using Regions to Discover Concurrency

**prof.dr.ir. Wil van der Aalst**
**www.processmining.org**




Technische Universiteit Eindhoven University of Technology

**Where innovation starts**

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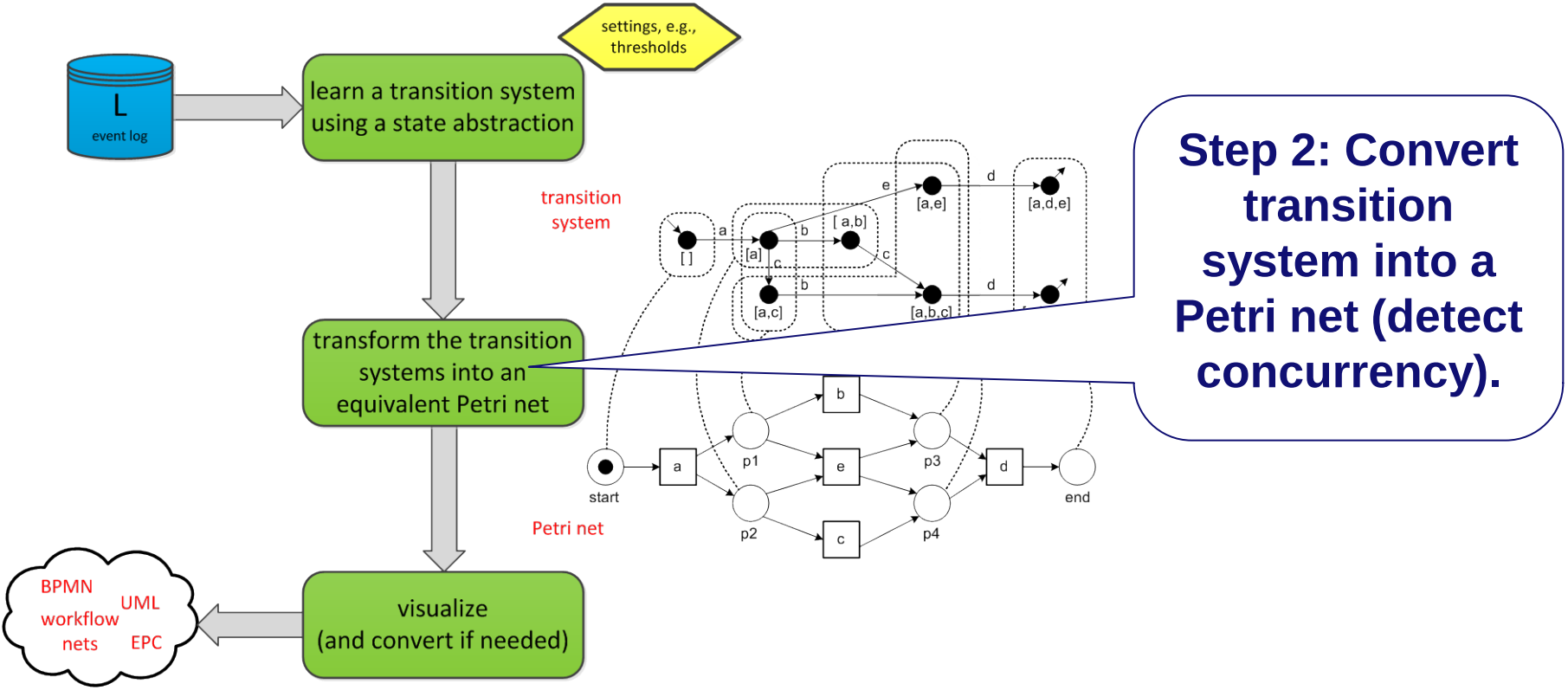
# State-based regions




**Step 2: Convert transition system into a Petri net (detect concurrency).**

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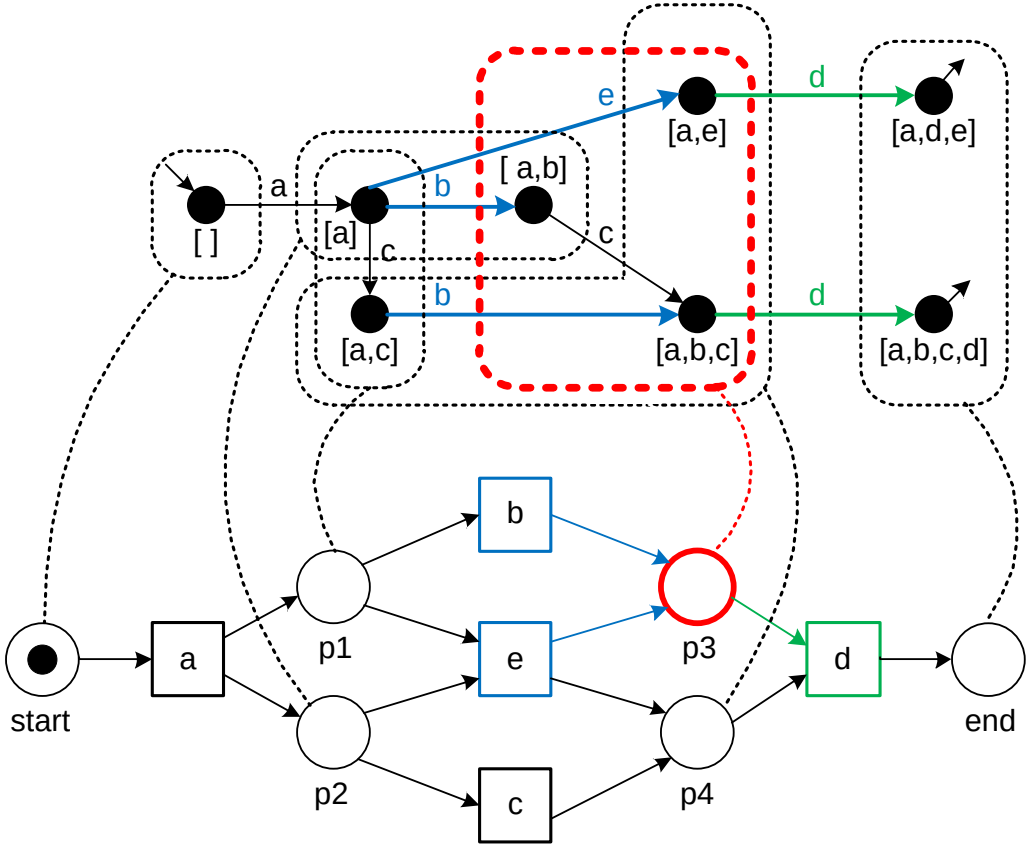
# State-based regions correspond to places

**It is all about discovering concurrency …**

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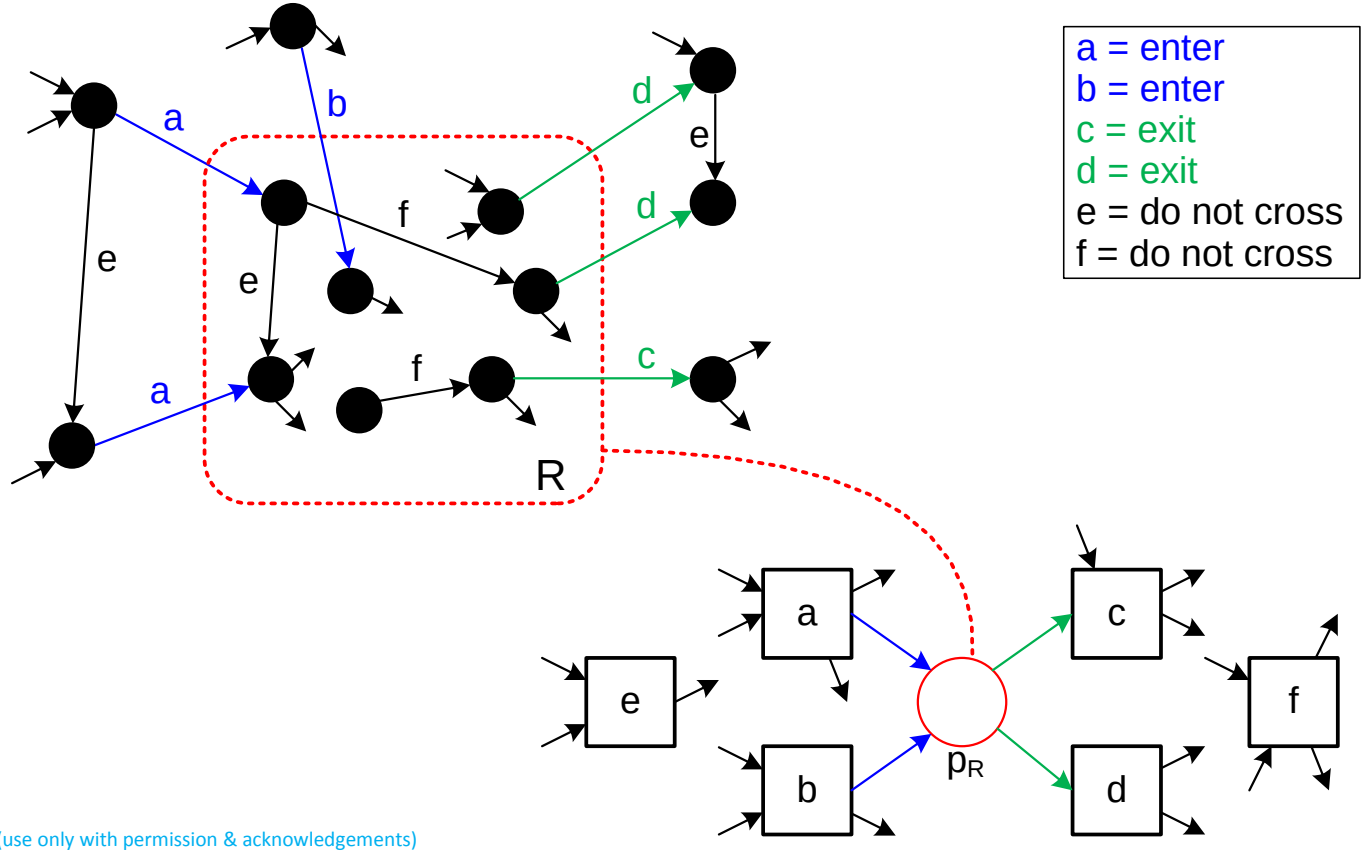
# What is a (state-based) region?

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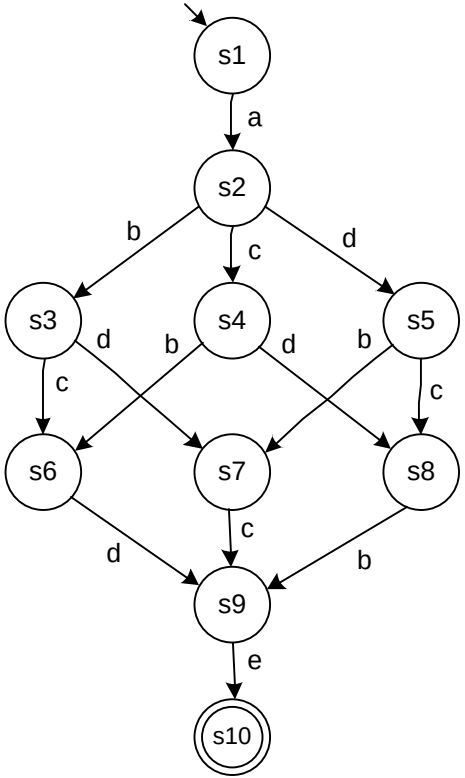
# Starting point: A transition system




- We assume that there is only one initial state (otherwise preprocessing needed).
- It is convenient to also have just one final state that can always be reached (not strictly necessary)
- All states need to be reachable!

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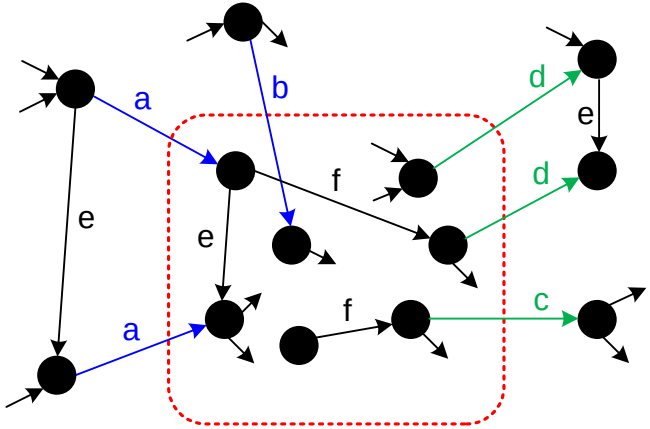
# Definition

**A region is a set of states, such that, if a transition *exits* the region, then all equally labeled transitions *exit* the region, and if a transition *enters* the region, then all equally labeled transitions *enter* the region. All events not entering or exiting the region *do not cross* the region.**

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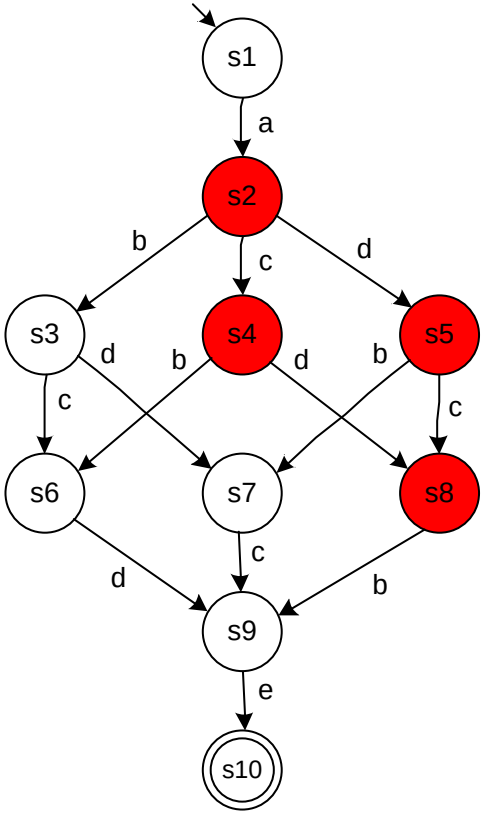
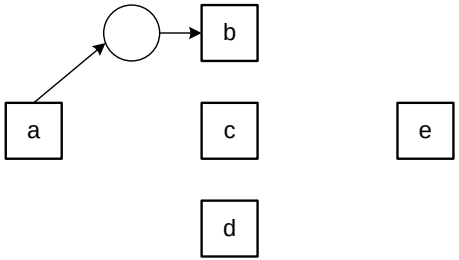
# Example of a region




- a enters
- b exits
- c does not cross
- d does not cross
- e does not cross

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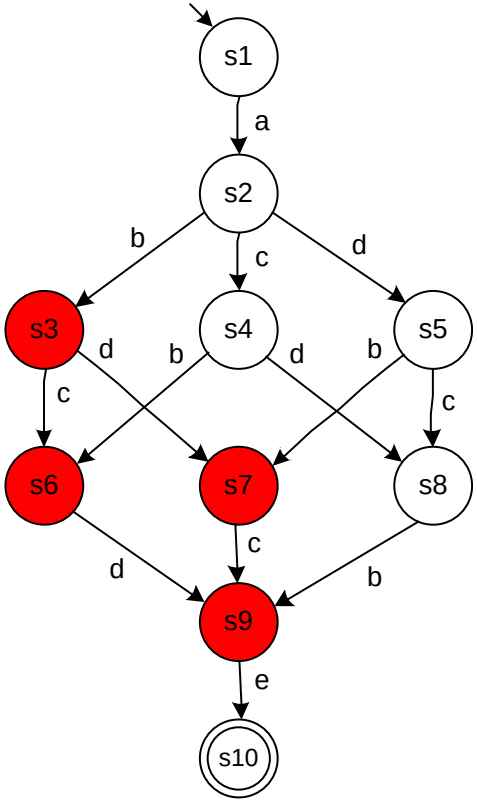
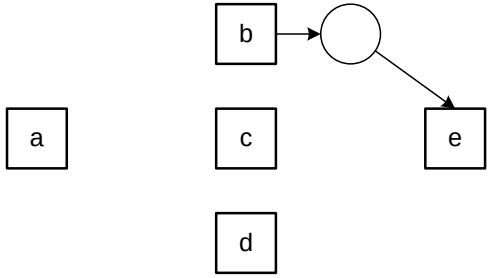
# Example of a region




- a does not cross
- b enters
- c does not cross
- d does not cross
- e exits

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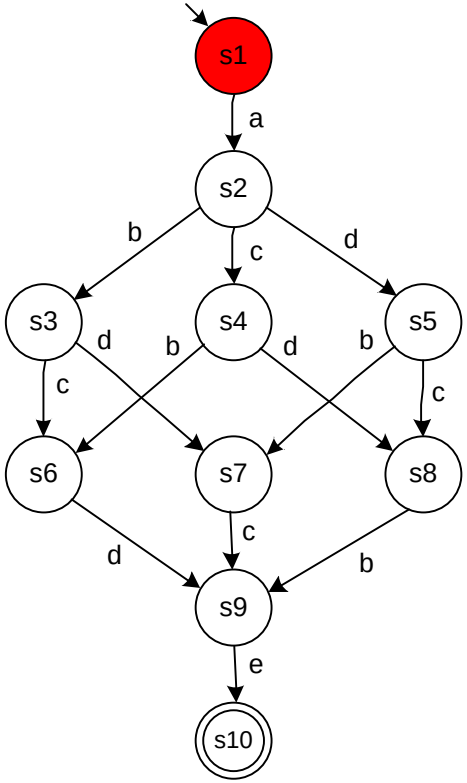
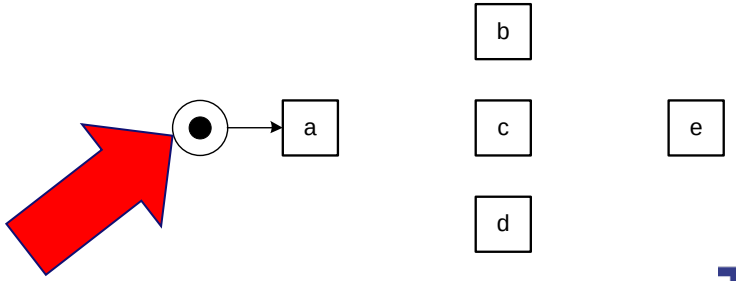
# Example of a region




- a exits
- b does not cross
- c does not cross
- d does not cross
- e does not cross

**As will be shown later: places corresponding to regions containing the initial state are initially marked.**

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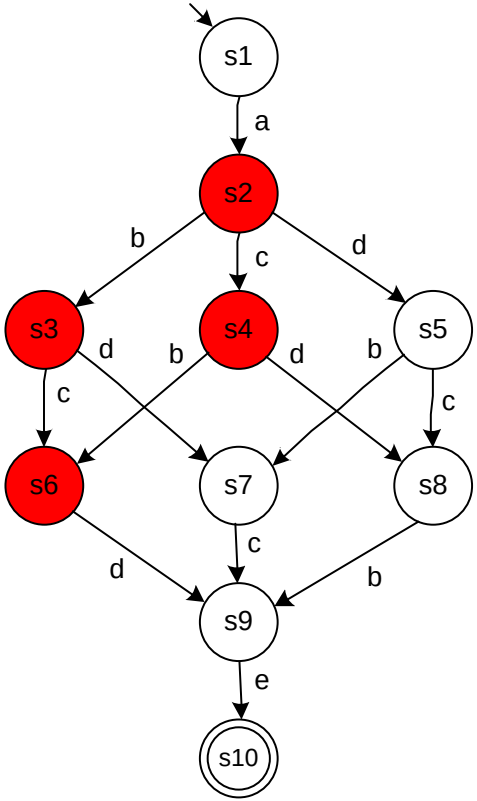
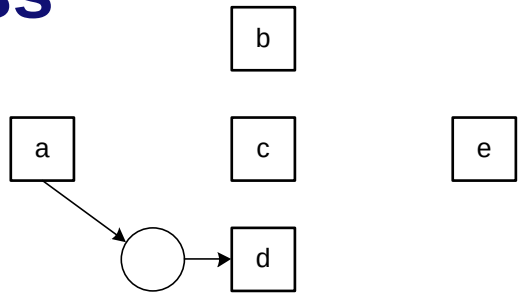
# Example of a region




- a enters
- b does not cross
- c does not cross
- d exits
- e does not cross

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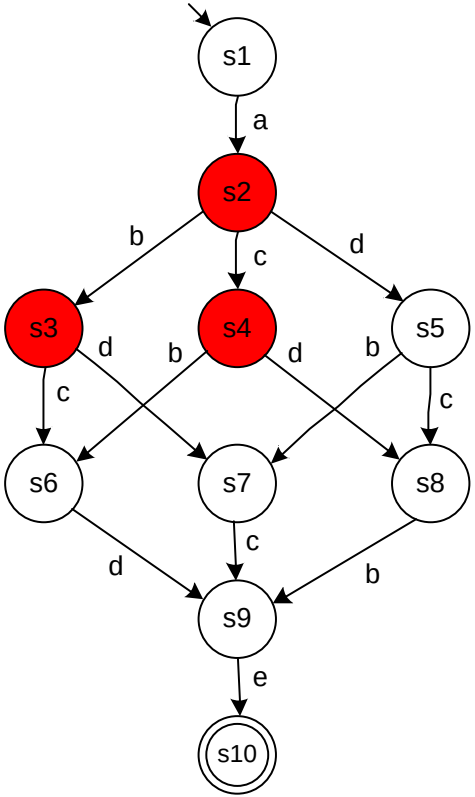
# Not a region




- a enters
- b does not cross and exits
- c does not cross and exits
- d does not cross and exits
- e does not cross

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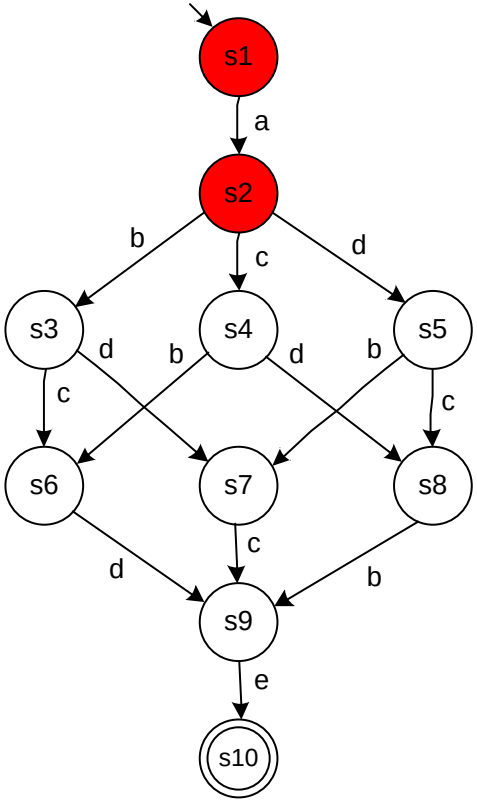
# Not a region




- a does not cross
- b does not cross and exits
- c does not cross and exits
- d does not cross and exits
- e does not cross

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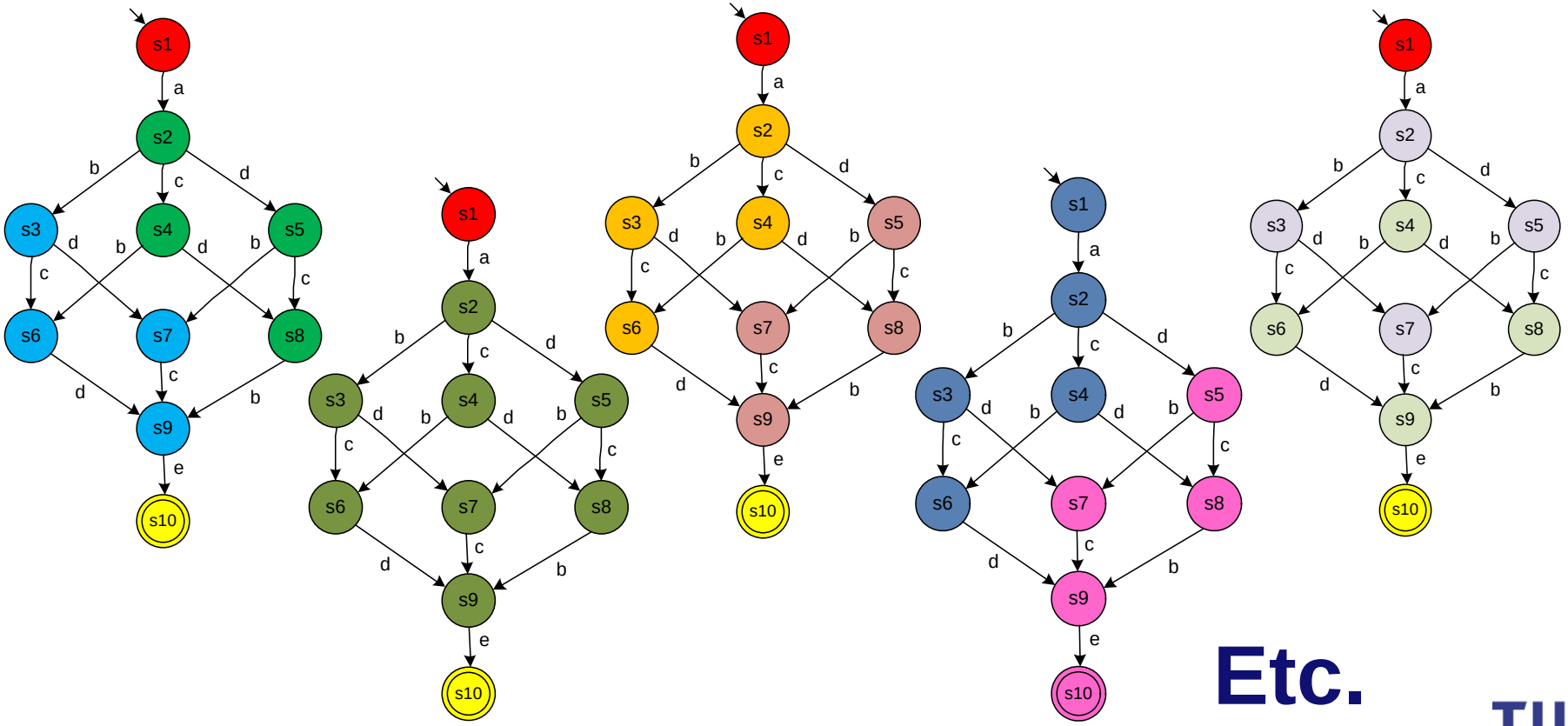
# Multiple regions

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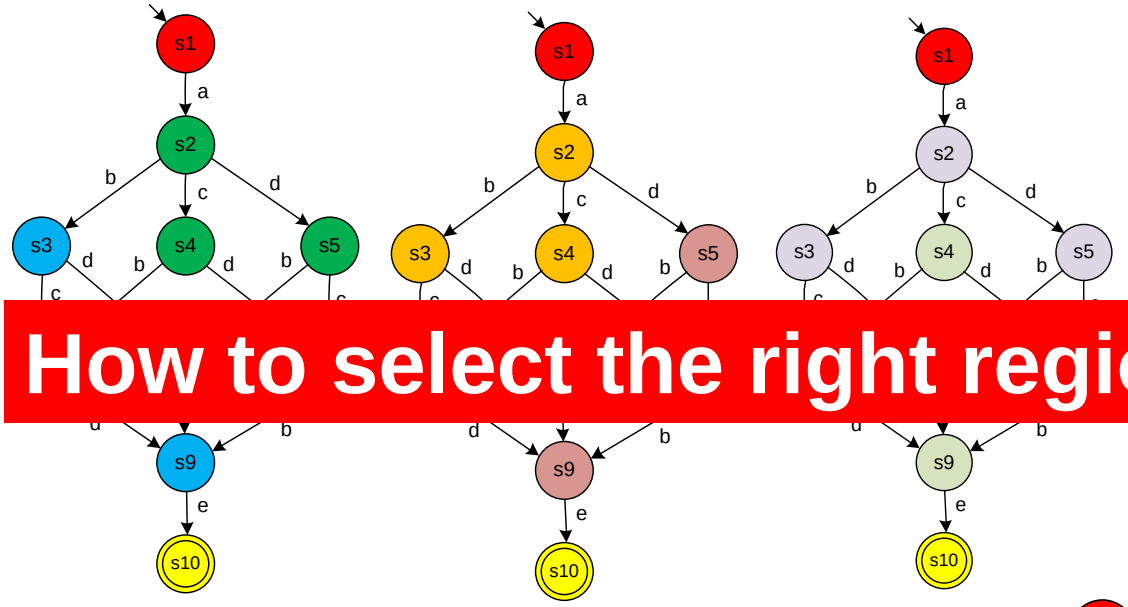
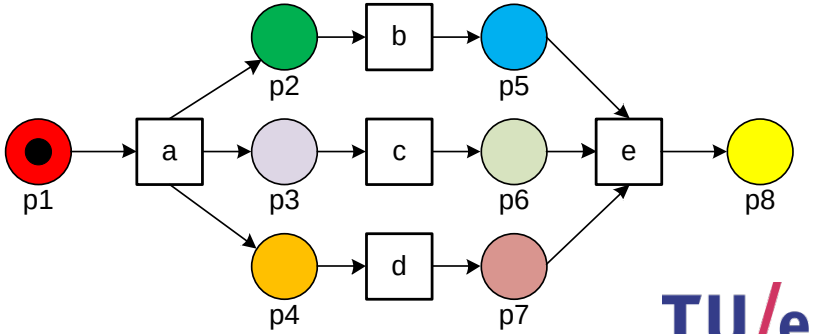
# Selectively chosen regions




**How to select the right regions?**

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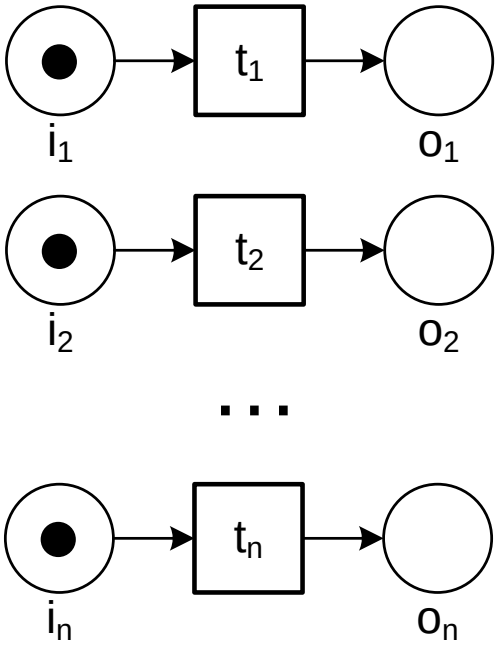
# Question




**How many regions does the reachability graph of this Petri net have?**

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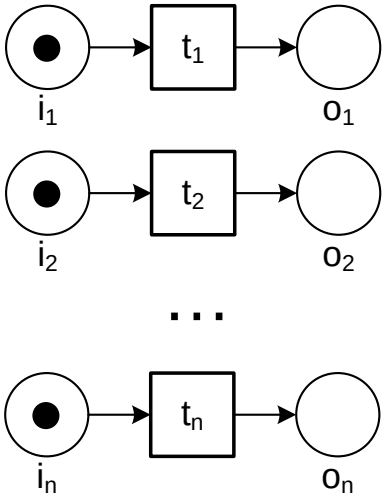
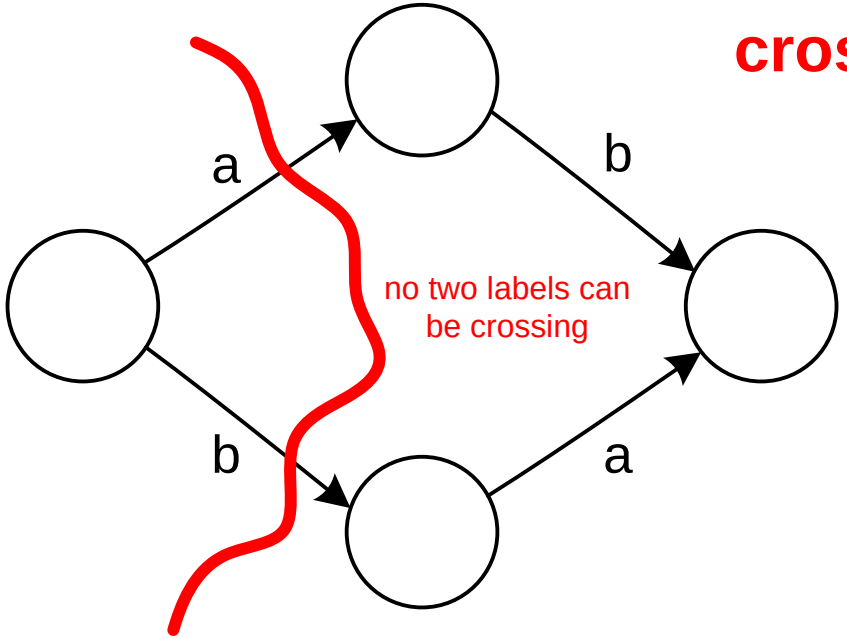
# Answer: 2(n+1) regions




**$2^n$ states**




**At most 1 transition label can be crossing (or none).**

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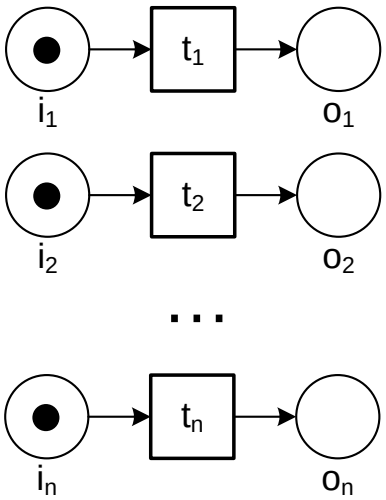
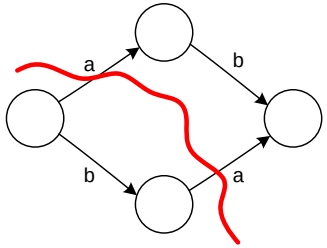
# Answer: 2(n+1) regions




- There are *n* ways to split the states in two groups based on the label selected to cross.
- Each situation splits the set of states in two regions.
- Also the empty set and all the set of all states are regions.

**Answer: 2(n+1) regions.**

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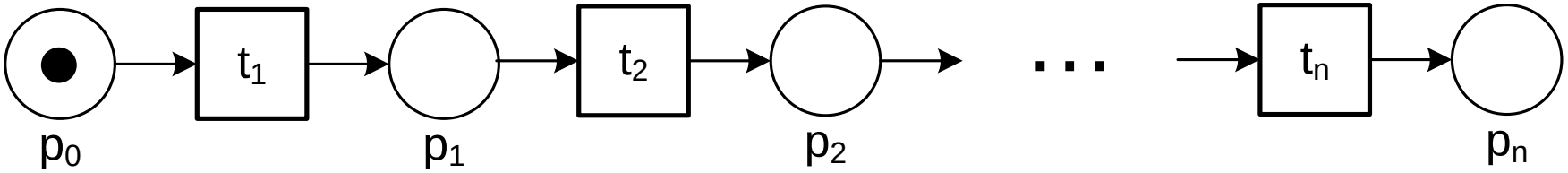
# Question




**How many regions does the reachability graph of this Petri net have?**

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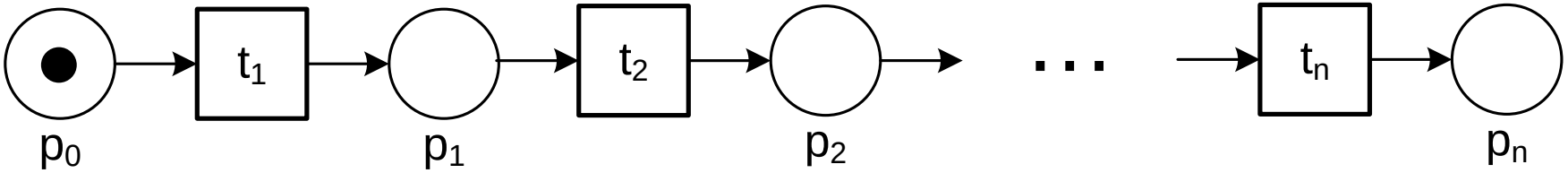
# Answer




**Every subset of states forms a region.**
**Hence, there are $2^{(n+1)}$ regions.**

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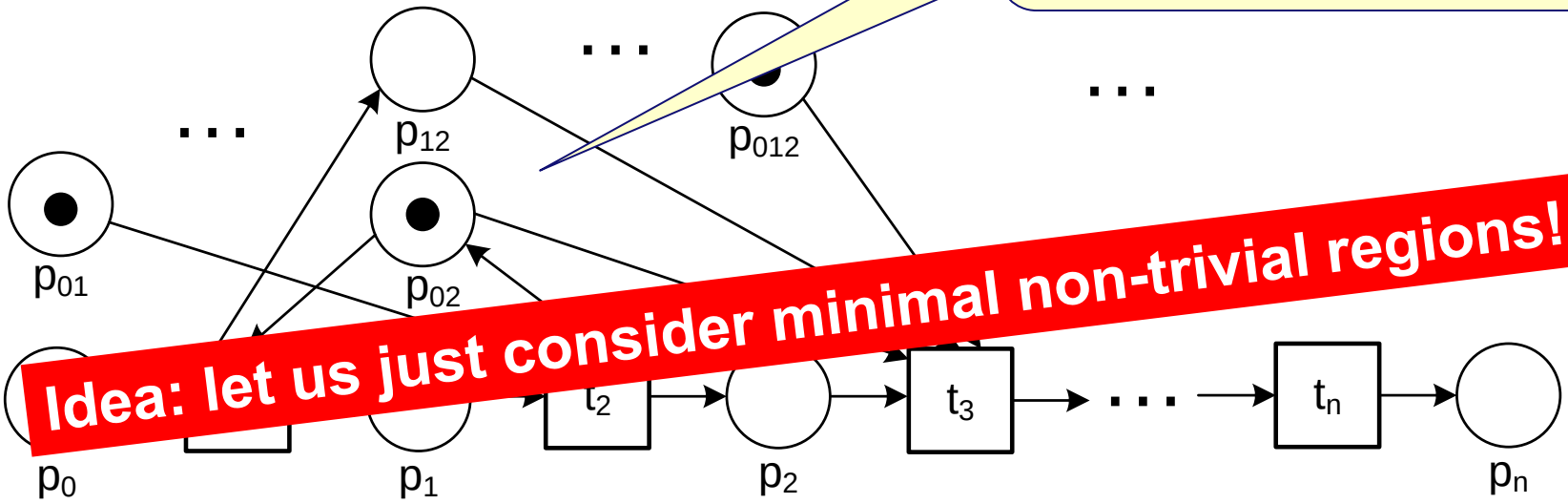
# Illustration




**For a sequence of 10 activities we have $2^{(10+1)} = 2048$ regions.**

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# Selecting the "interesting regions" only …

- **We only include the non-trivial minimal regions!**
- **Non-trivial**
  - **The empty set and the set of all states are regions by definition.**
  - **These trivial regions carry no information and should not be included.**
- **Minimal**
  - **A region is minimal if it cannot be decomposed into smaller (non-trivial) ones.**
  - **Non-minimal regions are implied by smaller ones and should not be included.**

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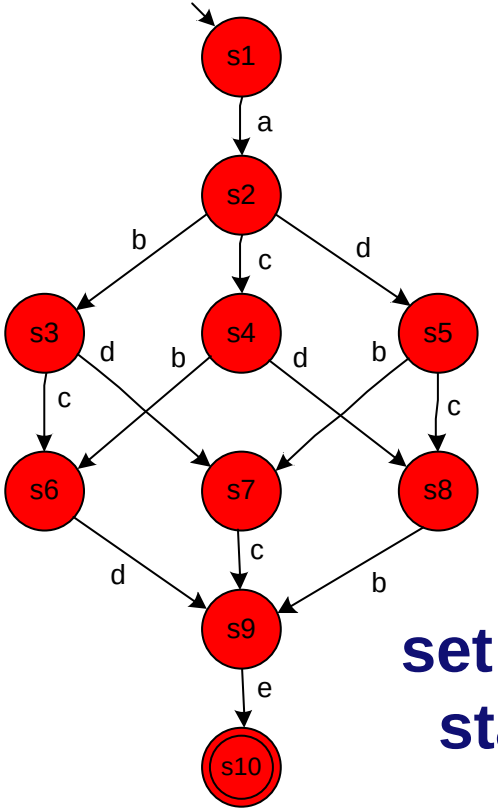
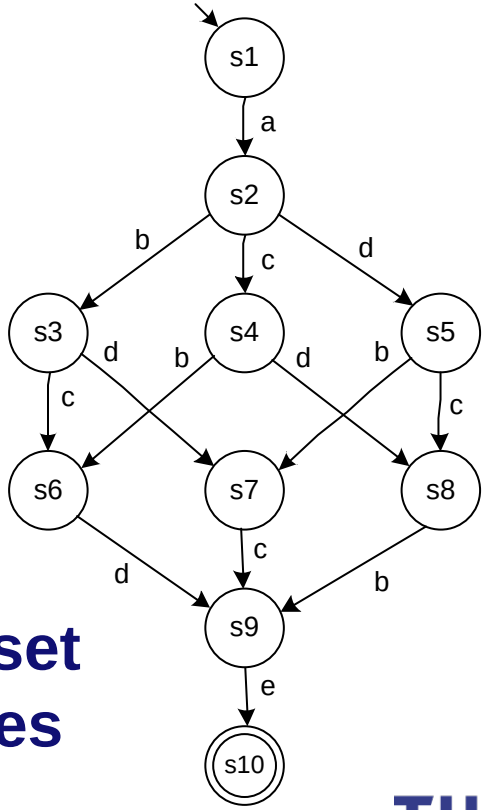
# Trivial regions: All or nothing




**a,b,c,d,e do not cross**

**set of all states**

**empty set of states**

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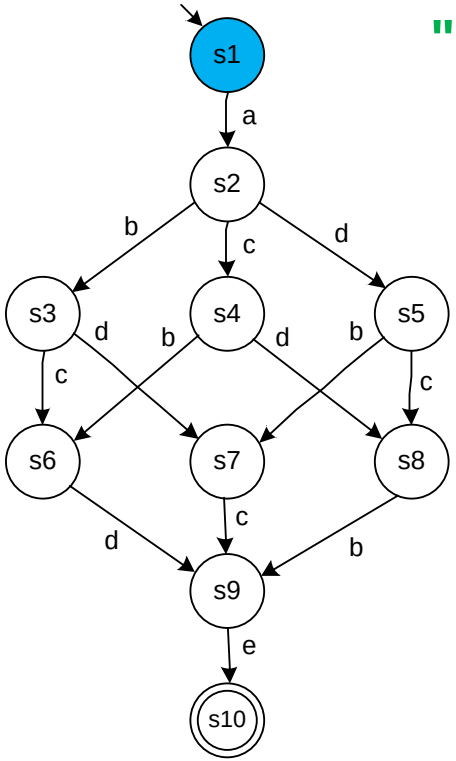
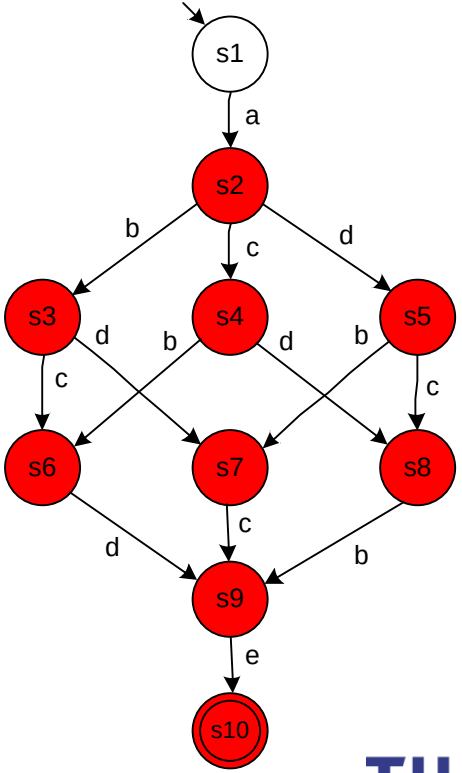
# Complement:
# If *r* is a region, then *S*\ *r* is a region




"exits" and "enters" are swapped

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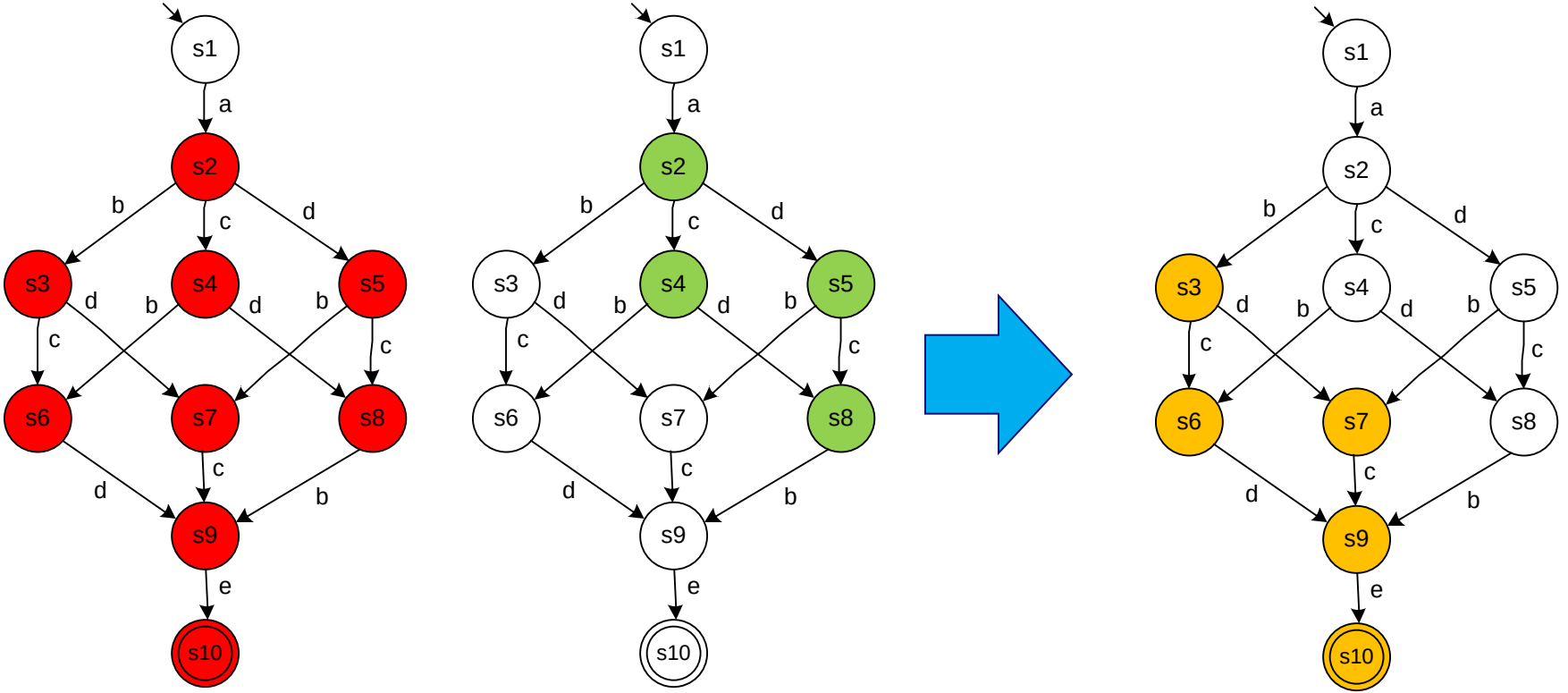
# If $r_1$ and $r_2$ are regions, and $r_1$ is a subset of $r_2$, then $r_2 \setminus r_1$ is a region.

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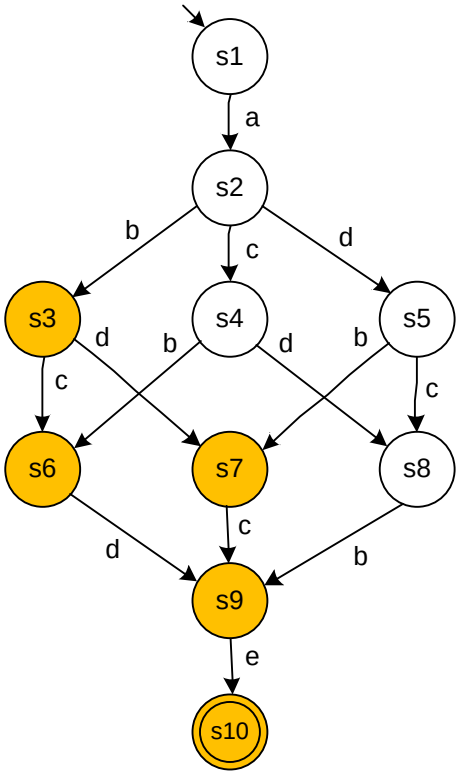
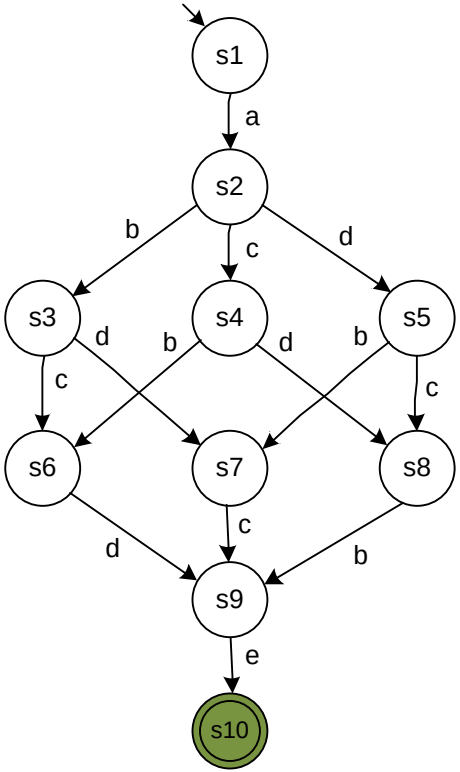
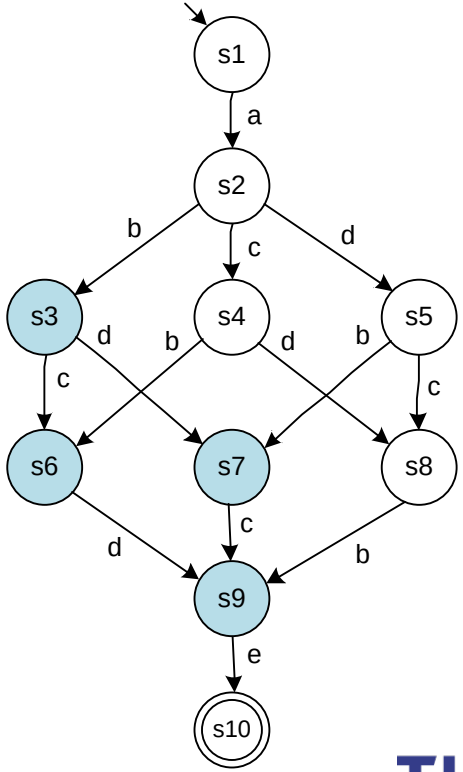
# Not minimal yet …

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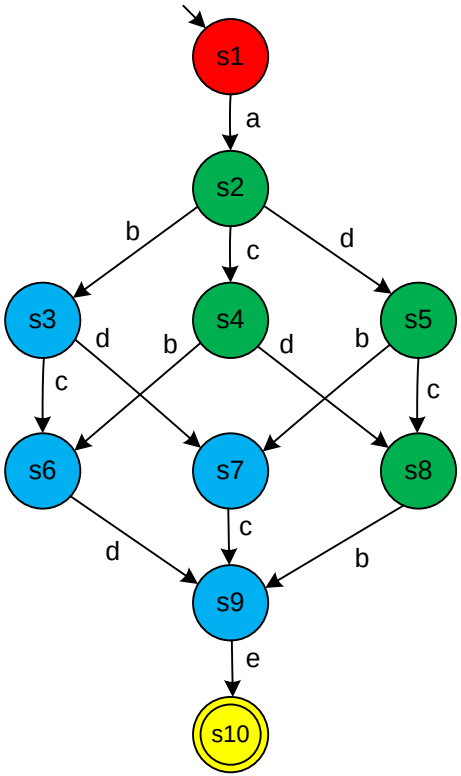
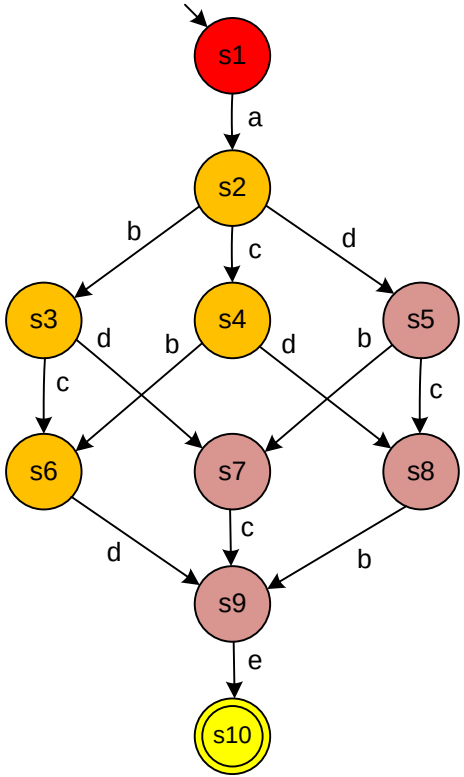
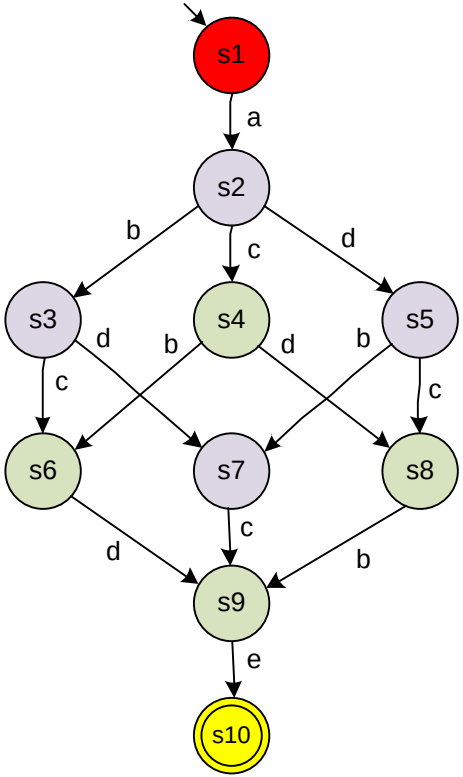
# Running example:
# 8 minimal non-trivial regions

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# Basic algorithm to construct a Petri net

1. For each transition label in the transition system, a transition is added to the Petri net.
2. The minimal non-trivial regions are computed.
3. For each minimal non-trivial region in the transition system, a place is added to the Petri net.
4. The corresponding arcs are generated.
5. A token is added to each place that corresponds to a region containing the initial state.

The resulting Petri net is called the minimal saturated net.

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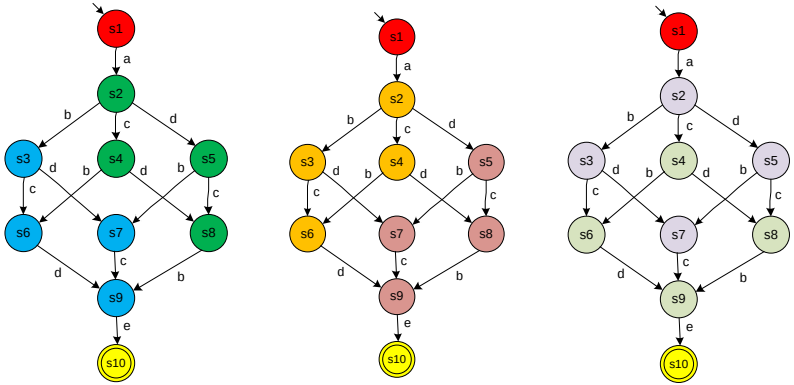
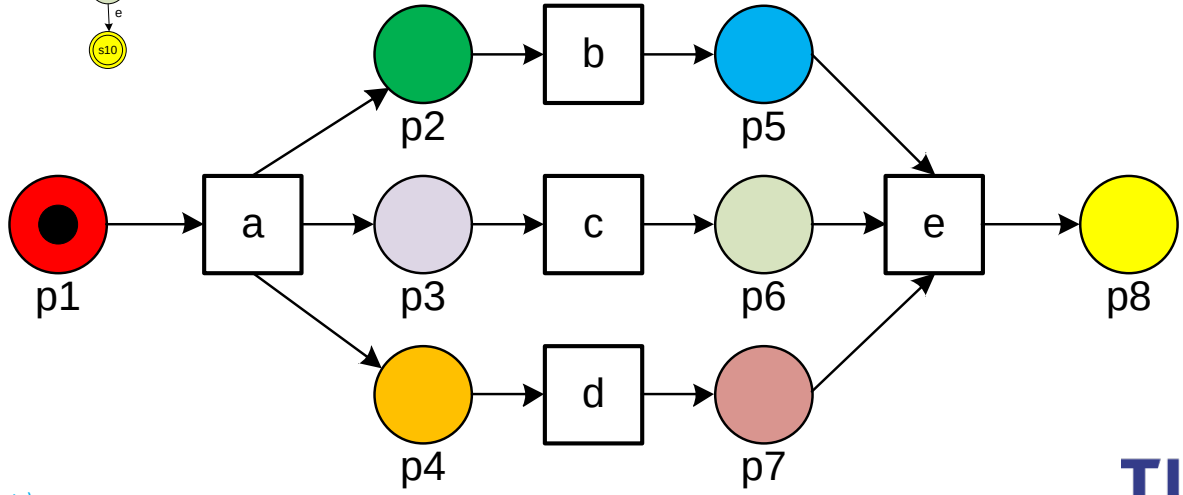
# Applying the algorithm yields the expected result

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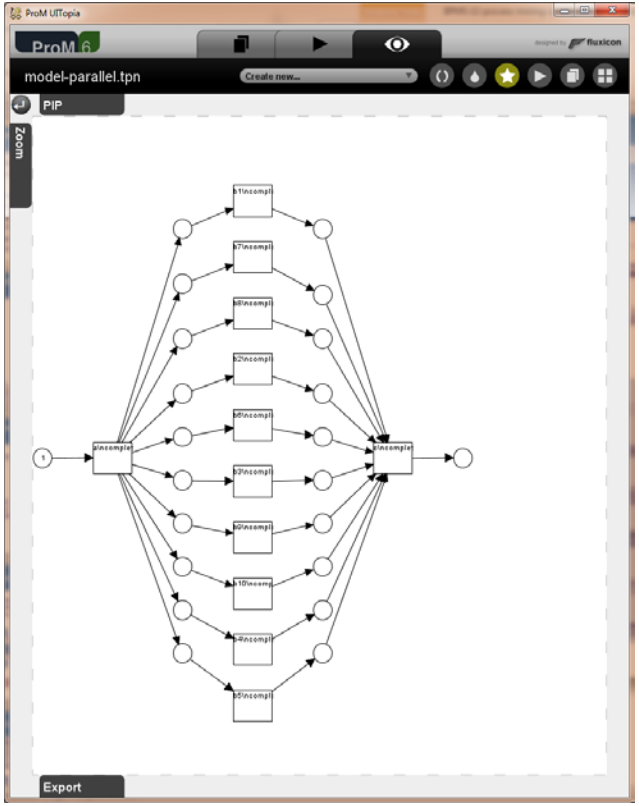
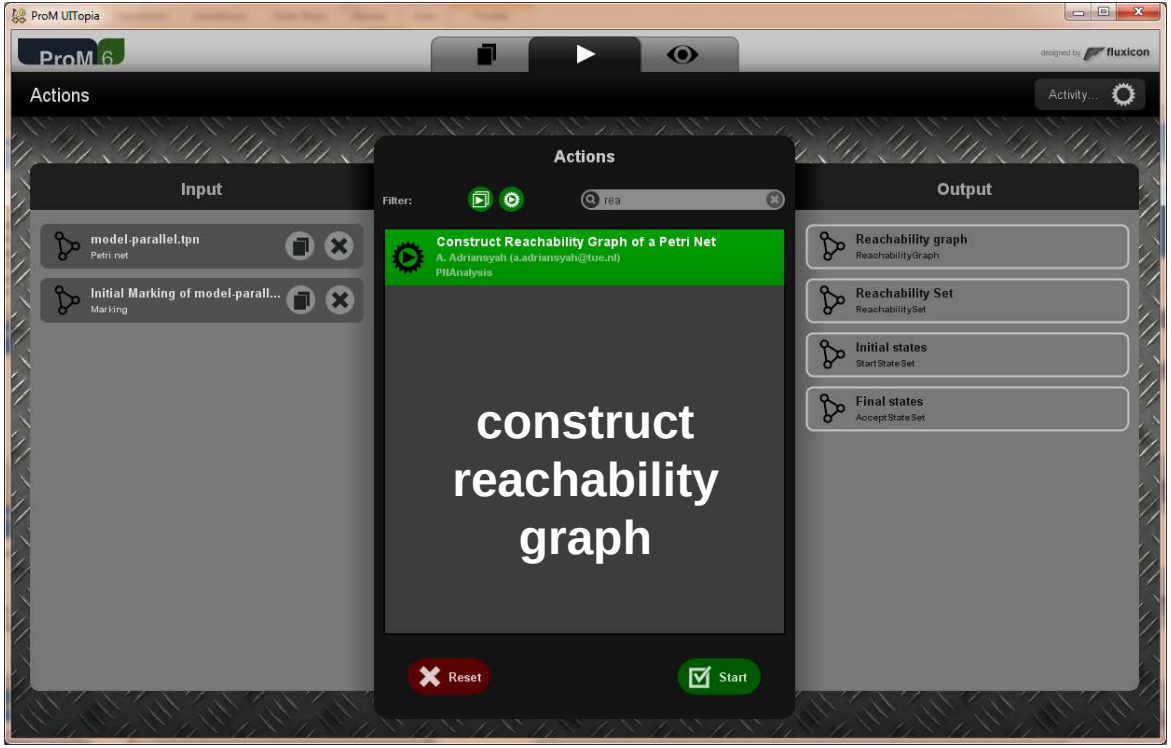
# Rediscovery experiment with 10 parallel activities




**past with multiset abstraction**

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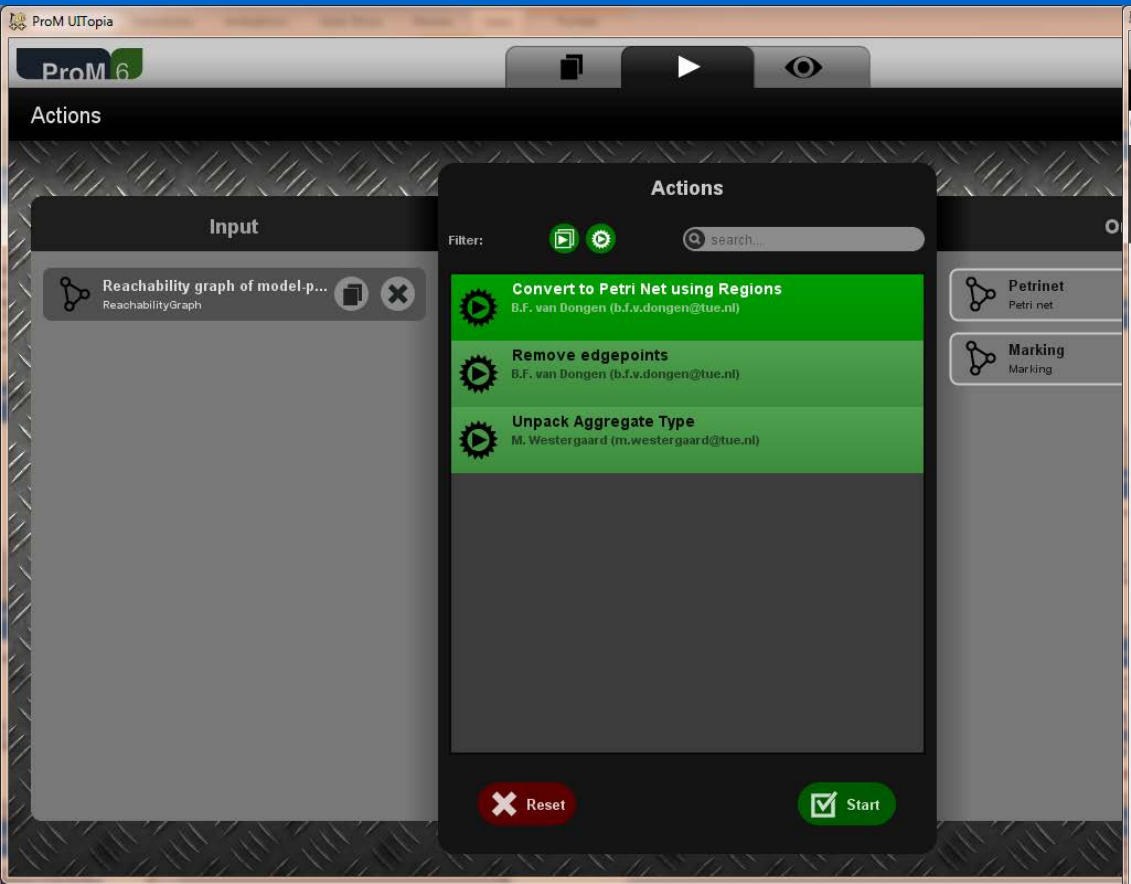
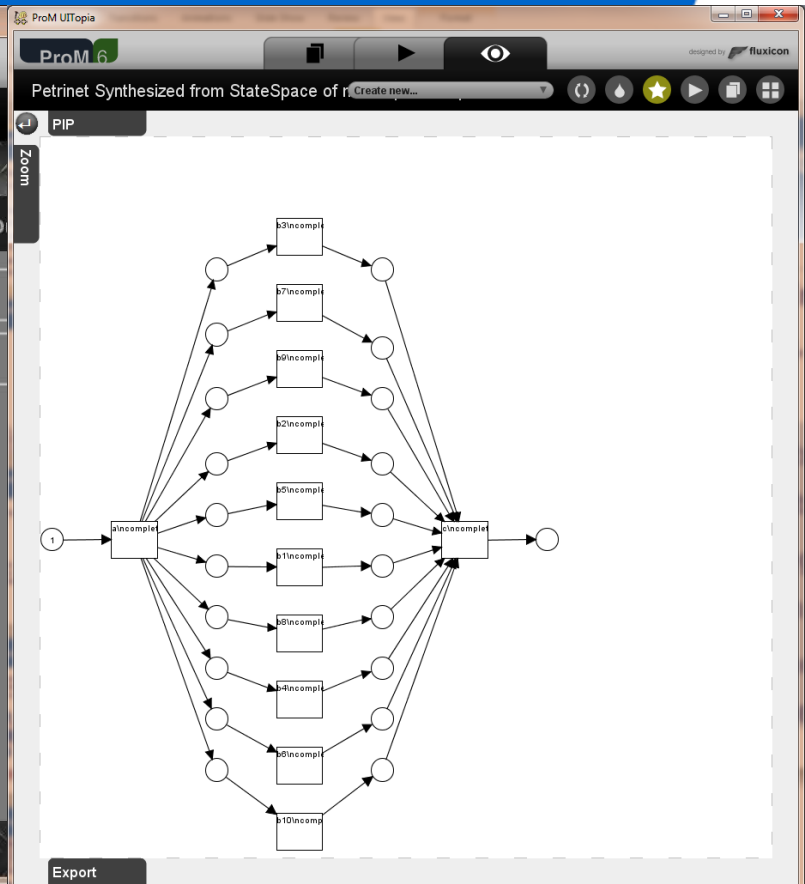
# Reachability graph ($1+2^{10}+1$ =1026 states)

# Apply "Covert to Petri net using regions"

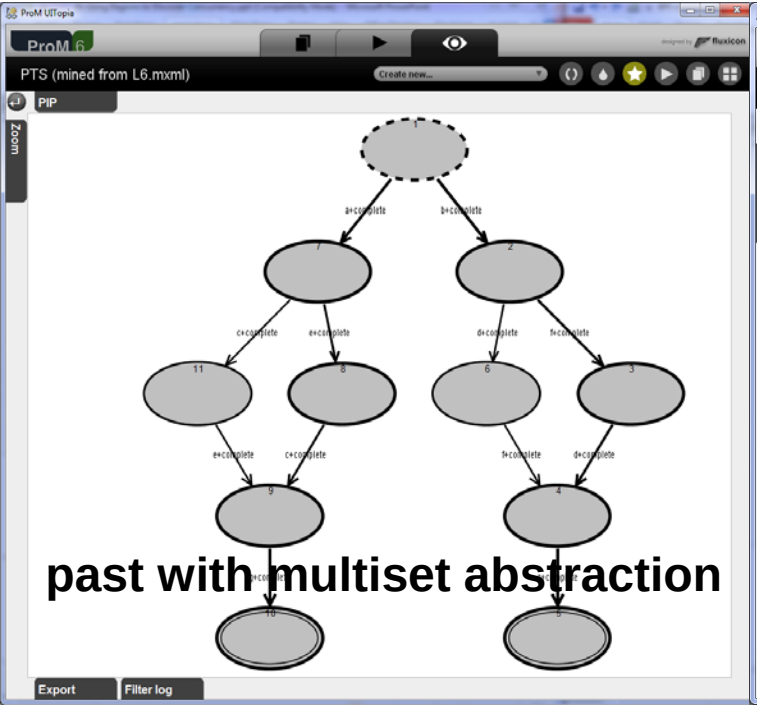


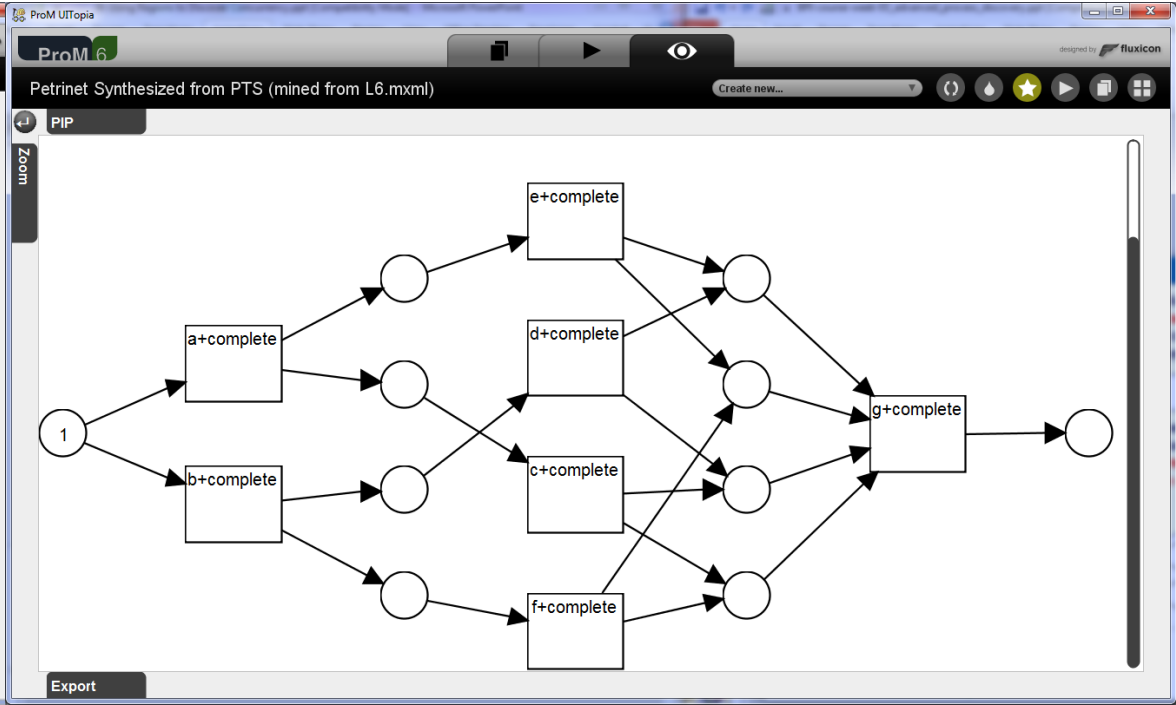
# Example

## (same result as Alpha algorithm)

$$L_6 = [\langle a,c,e,g\rangle^2, \langle a,e,c,g\rangle^3, \langle b,d,f,g\rangle^2, \langle b,f,d,g\rangle^4]$$

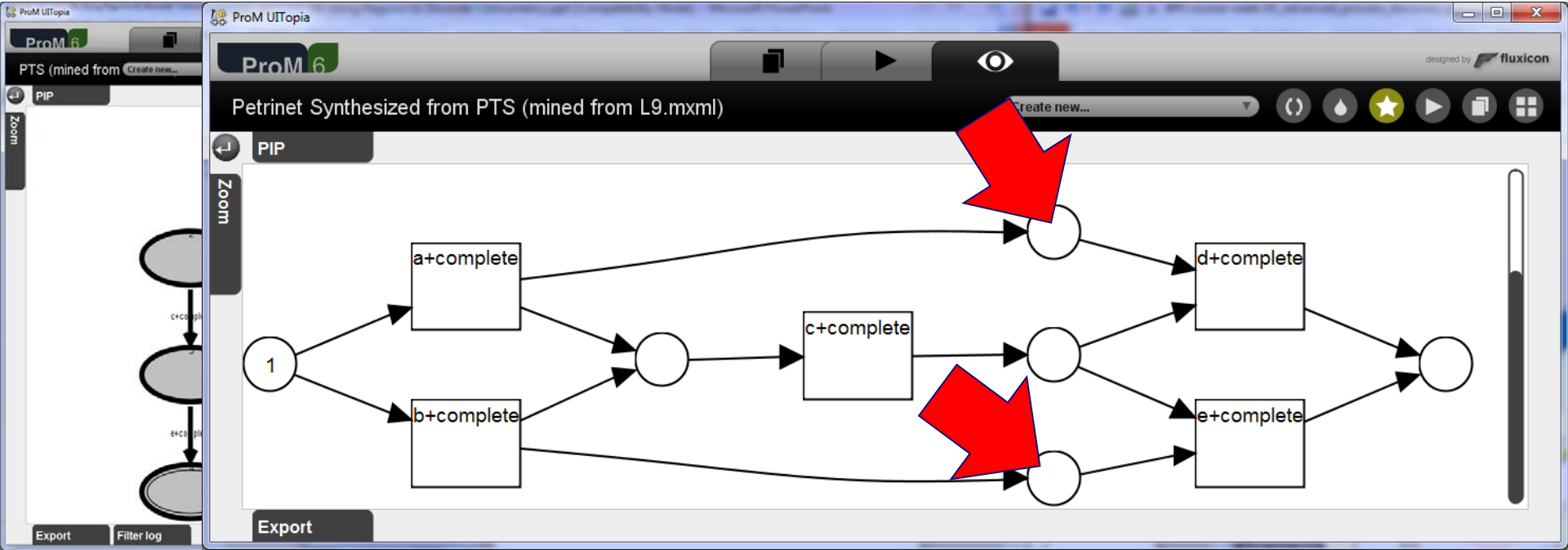



past with multiset abstraction

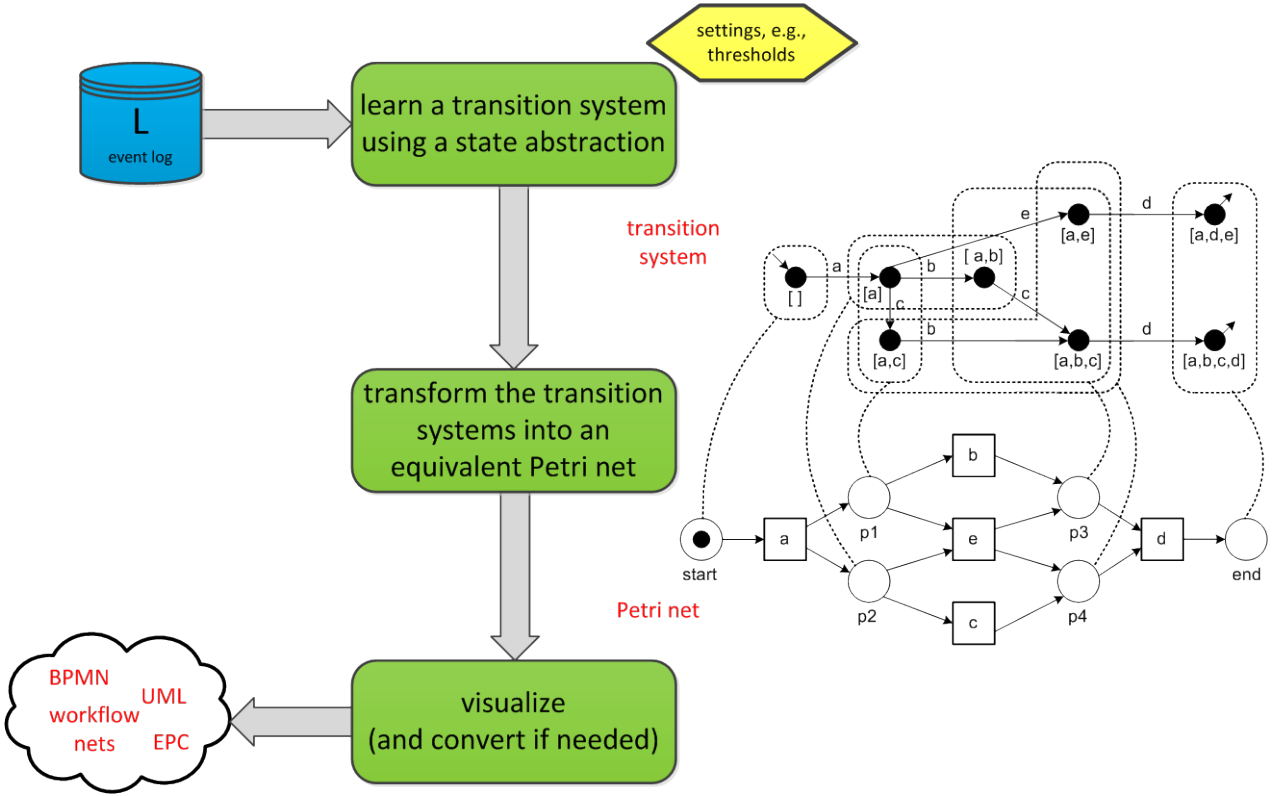


# Example
## (improved result compared to Alpha algorithm)

$$L_9 = [\langle a, c, d \rangle^{45}, \langle b, c, e \rangle^{42}]$$



# Next: limitations of the approach

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## Part I: Preliminaries

- Chapter 1: Introduction
- Chapter 2: Process Modeling and Analysis
- Chapter 3: Data Mining

## Part II: From Event Logs to Process Models

- Chapter 4: Getting the Data
- Chapter 5: Process Discovery: An Introduction
- Chapter 6: Advanced Process Discovery Techniques

## Part III: Beyond Process Discovery

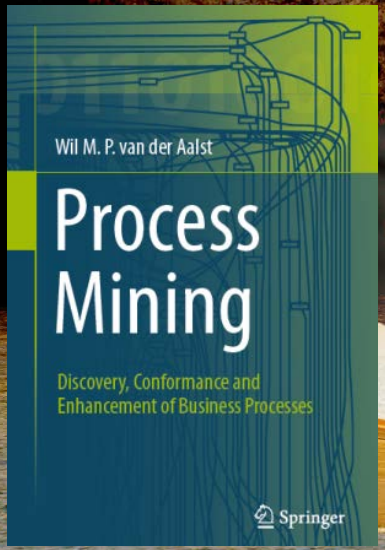
- Chapter 7: Conformance Checking
- Chapter 8: Mining Additional Perspectives
- Chapter 9: Operational Support

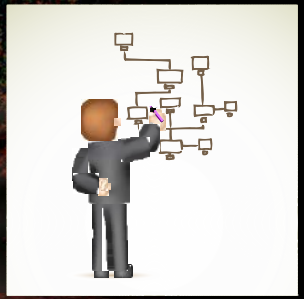
## Part IV: Putting Process Mining to Work

- Chapter 10: Tool Support
- Chapter 11: Analyzing "Lasagna Processes"
- Chapter 12: Analyzing "Spaghetti Processes"

## Part V: Reflection

- Chapter 13: Cartography and Navigation
- Chapter 14: Epilogue



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