Partial Orders Fit For Work

Jörg Desel FernUniversität in Hagen

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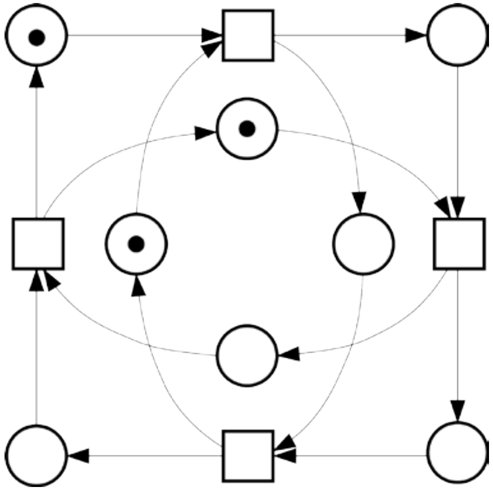
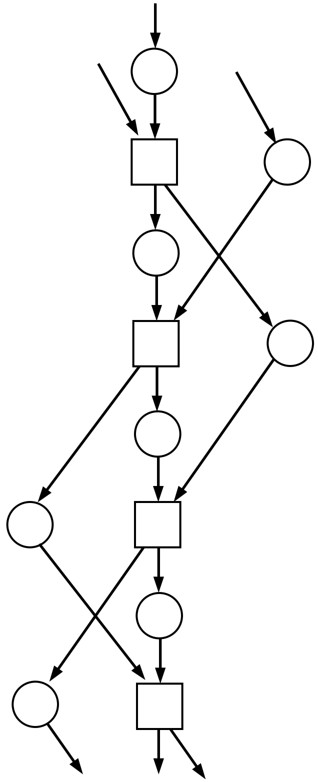
PART I:
A proof using partial orders (occurrence nets) work done in 1988 at GMD

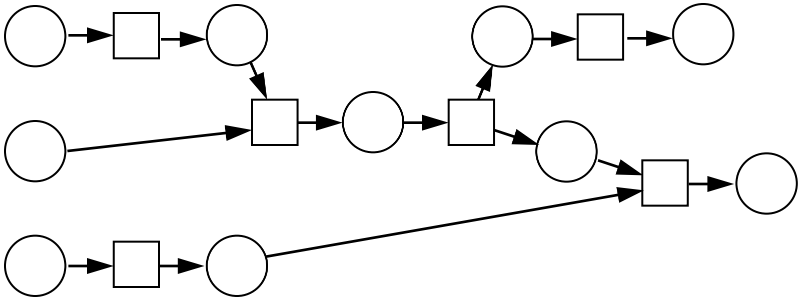
PART II:
Process Model Synthesis From Partial Orders (VIPtool)

PART I:
A proof using partial orders (occurrence nets) work done in 1988 at GMD



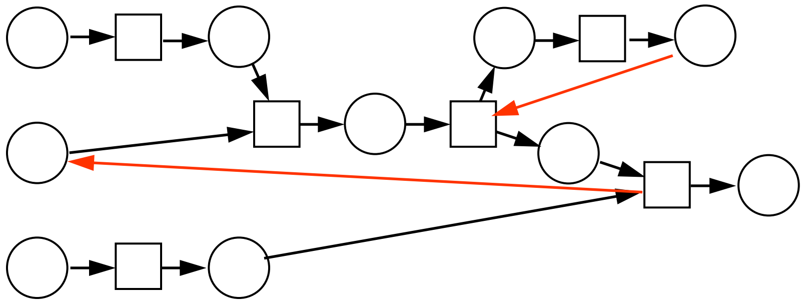


An **occurrence net** (B,E,K)



An **occurrence net** (B,E,K)

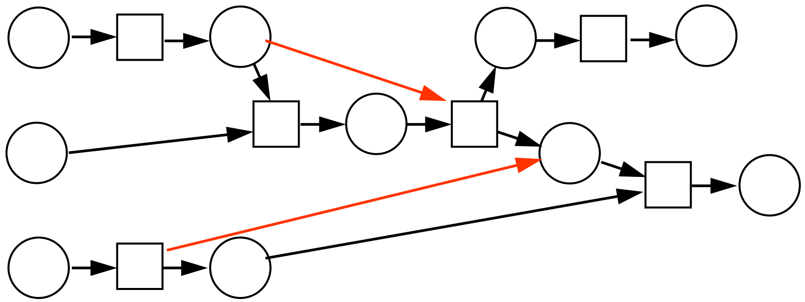
acyclic



An **occurrence net** (B,E,K)

acyclic

places unbranched

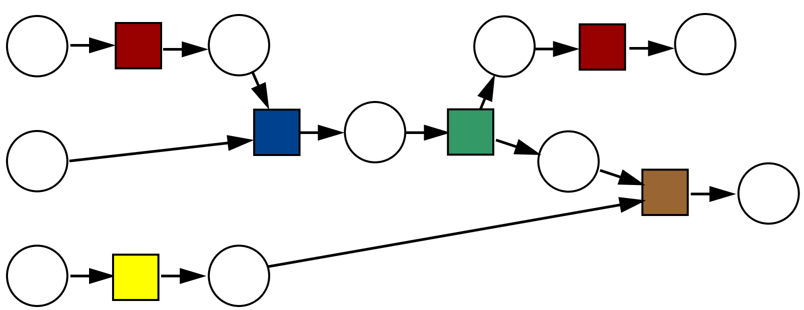


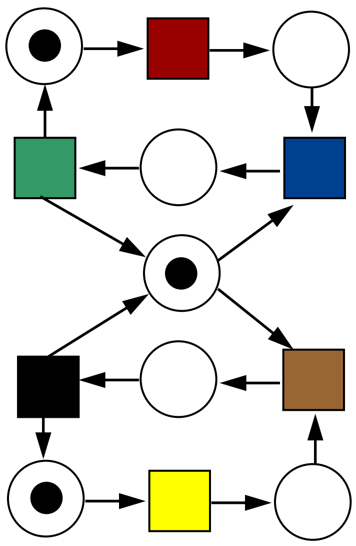
An **occurrence net** (B,E,K) of a **Petri net** (S,T,F)

acyclic

places unbranched

maps to the Petri net





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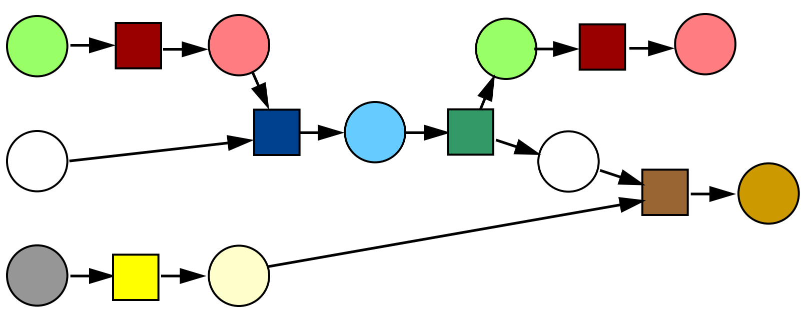
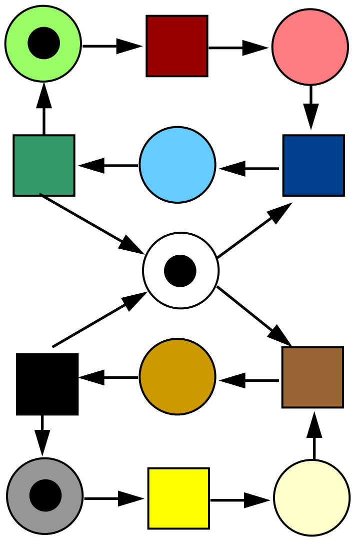
places unbranched

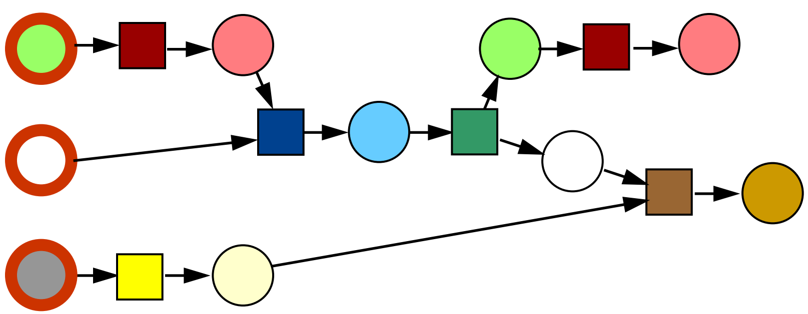
maps to the Petri net

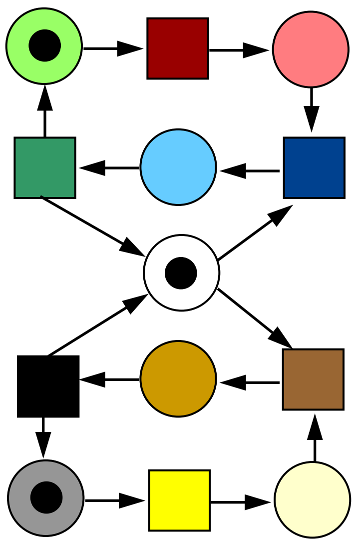




An **occurrence net** (B,E,K) of a **Petri net** (S,T,F)

acyclic
places unbranched
maps to the Petri net
minimal places map to tokens





An **occurrence net** (B,E,K) of a **Petri net** (S,T,F)

acyclic
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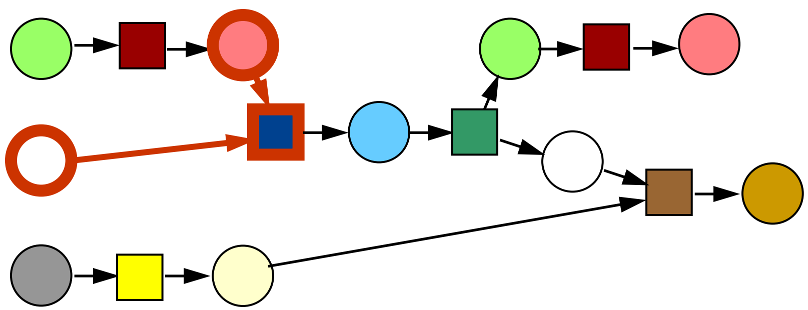
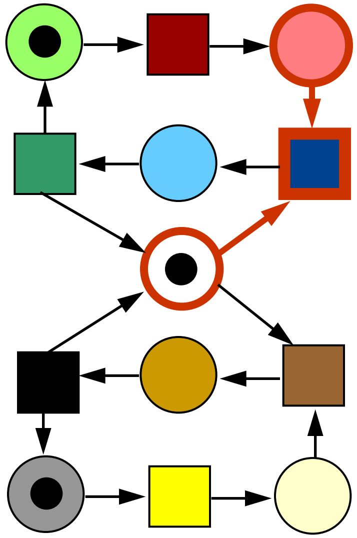
maps to the Petri net
minimal places map to tokens
presets of transitions map to presets of transitions





An **occurrence net** (B,E,K) of a **Petri net** (S,T,F)

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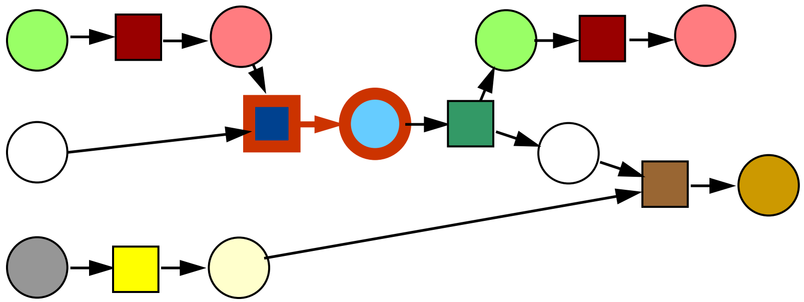
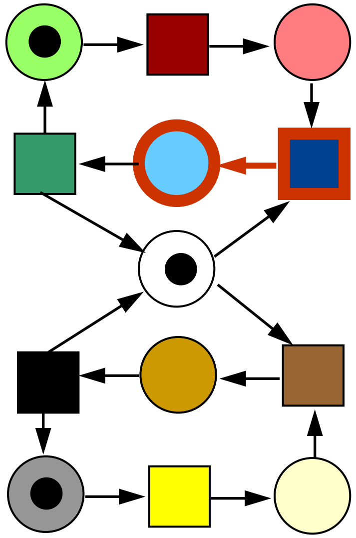
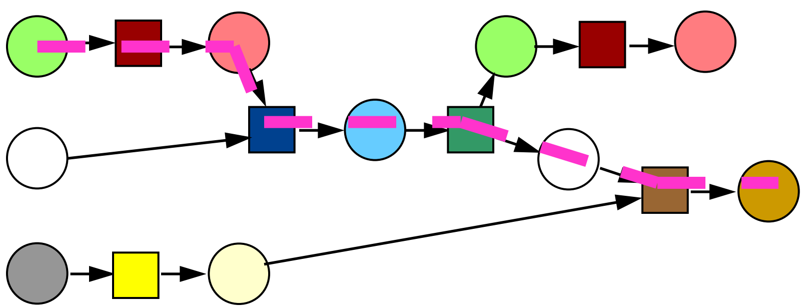
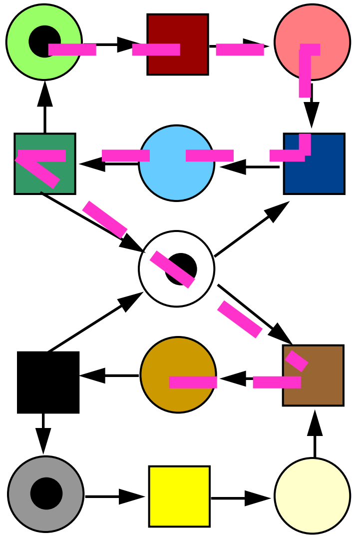




An **occurrence net** (B,E,K) of a **Petri net** (S,T,F)

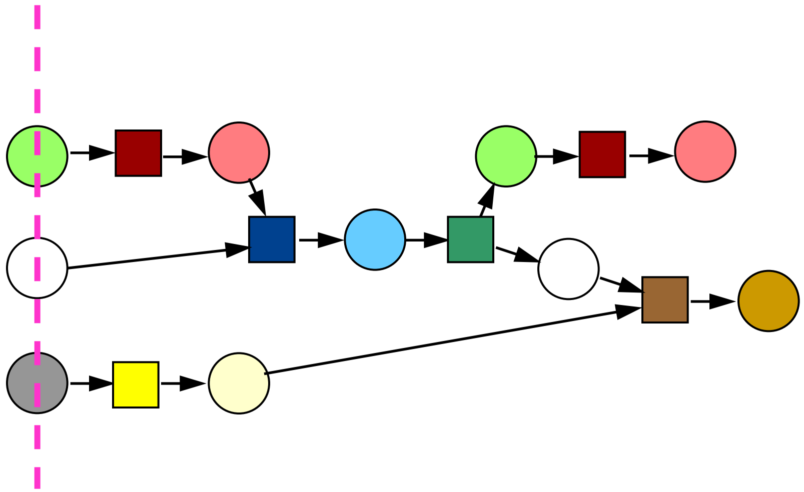
Lemma: paths map to paths

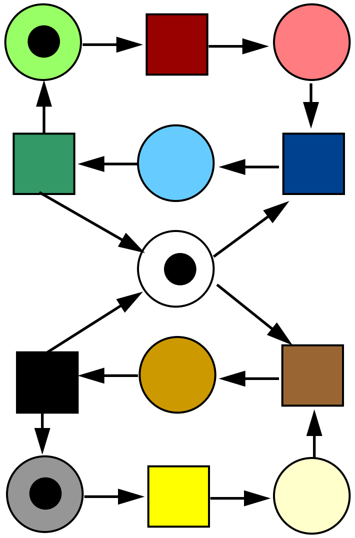




An **occurrence net** (B,E,K) of a **Petri net** (S,T,F)

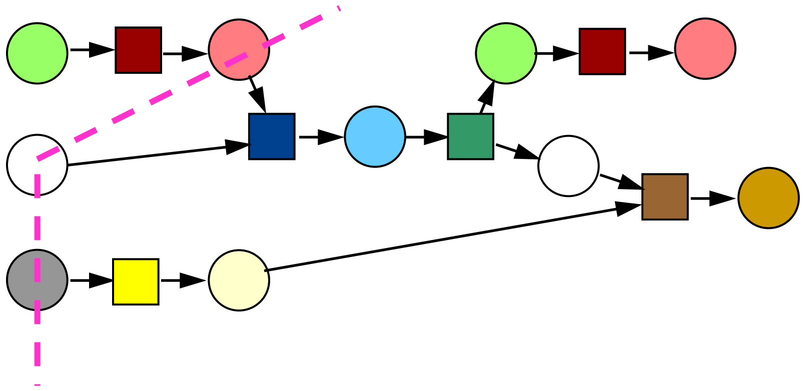
**Lemma: finite cuts
(max. sets of mutually concurrent places)
map to reachable markings**

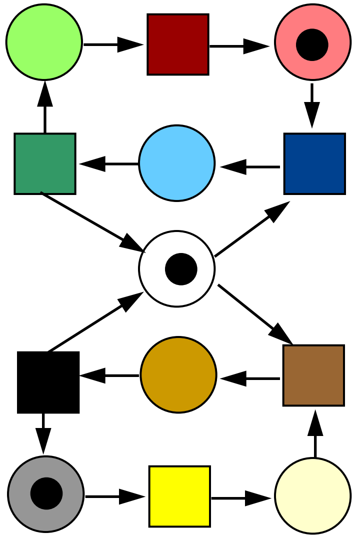




An **occurrence net** (B,E,K) of a **Petri net** (S,T,F)

Lemma: finite cuts (max. sets of mutually concurrent places) map to reachable markings





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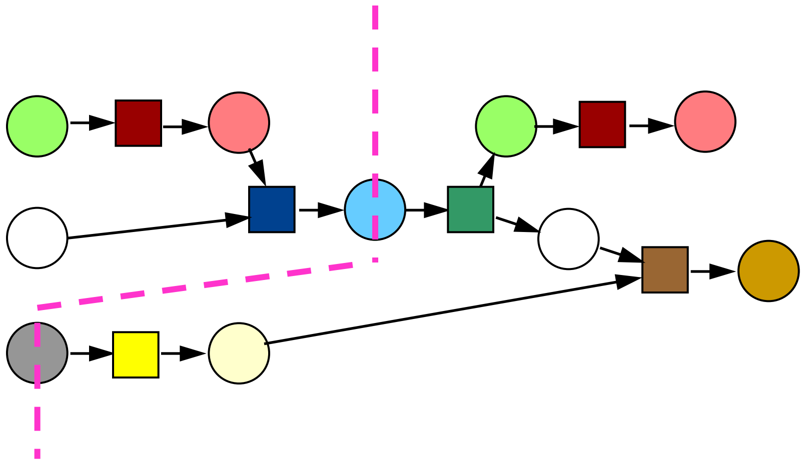

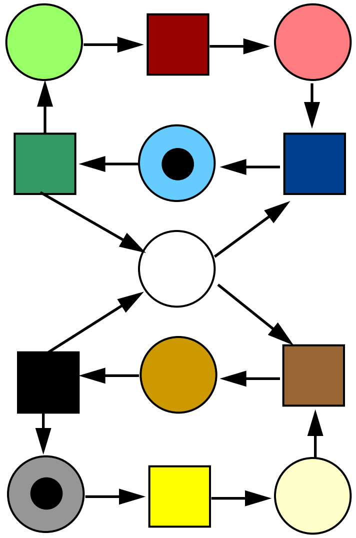

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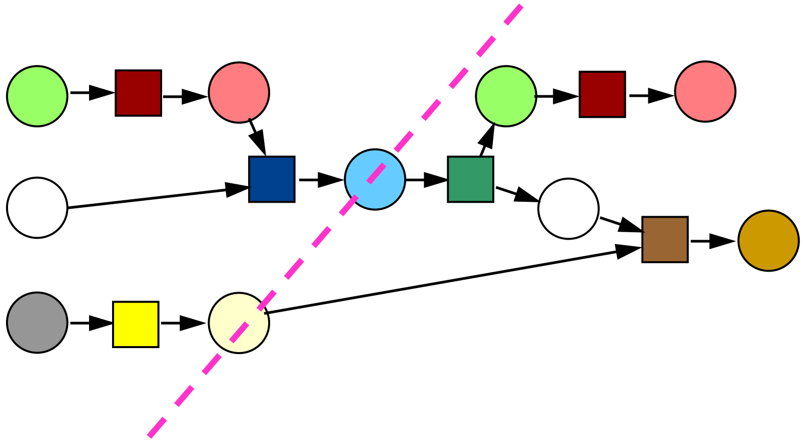

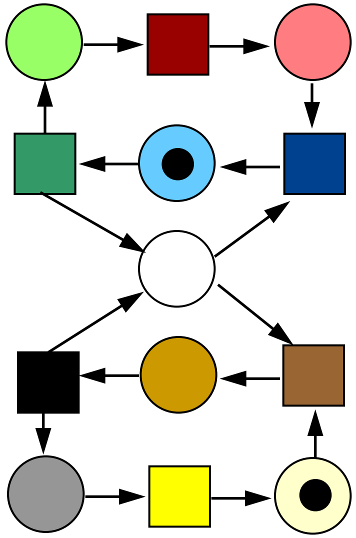

An **occurrence net** (B,E,K) of a **Petri net** (S,T,F)

Lemma: finite cuts
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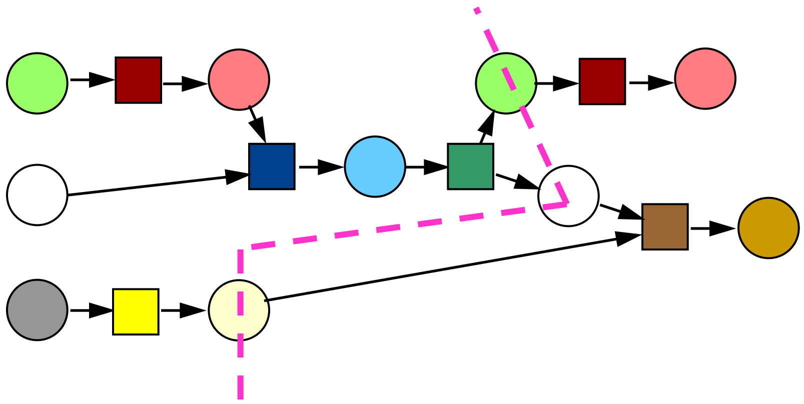
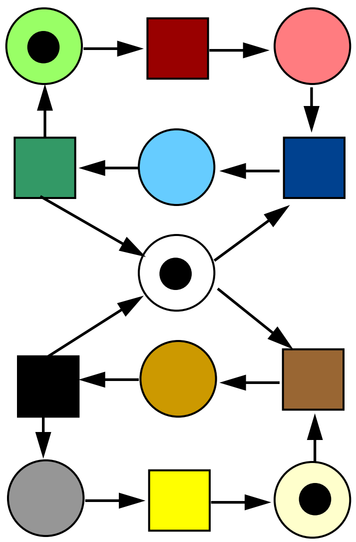
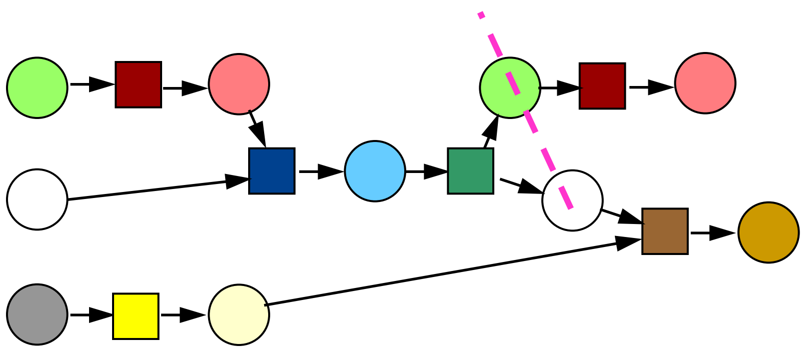
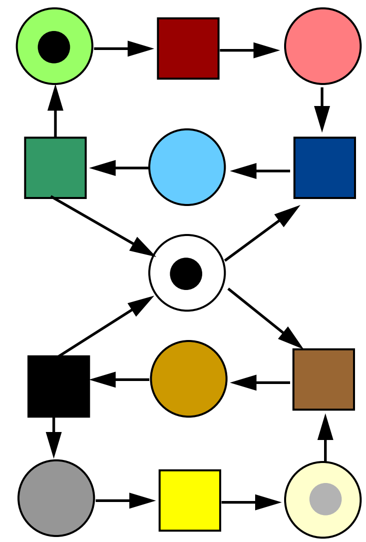




An **occurrence net** (B,E,K) of a **Petri net** (S,T,F)

**Corollary: finite co-sets
(sets of mutually concurrent places)
map to reachable sub-markings**





Theorem: each connected live and bounded Petri net is strongly connected

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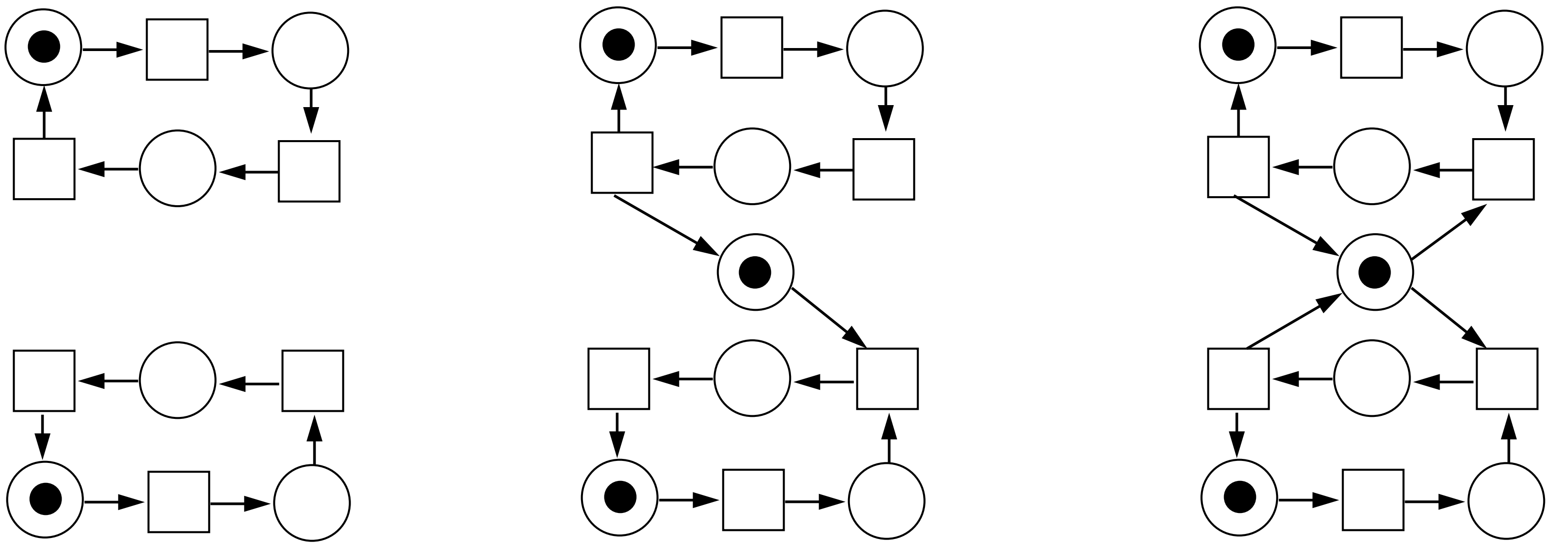
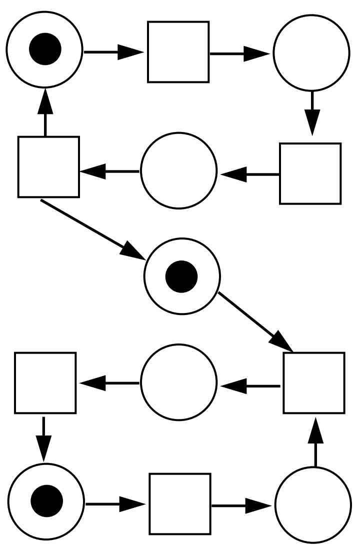
not connected | connected | strongly connected



Theorem: each connected live and bounded Petri net is strongly connected

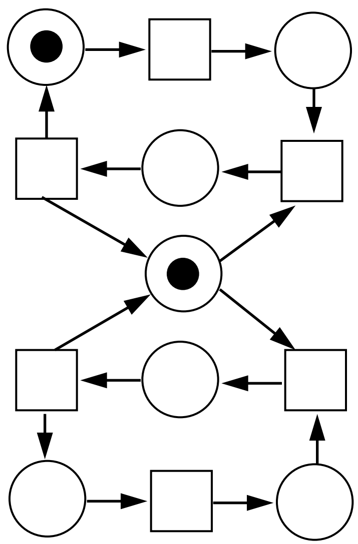
live, not bounded

each transition can always occur again

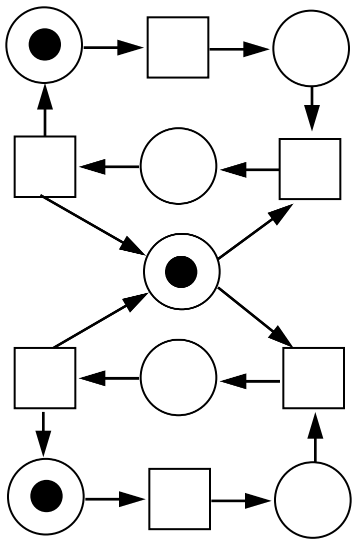


bounded, not live

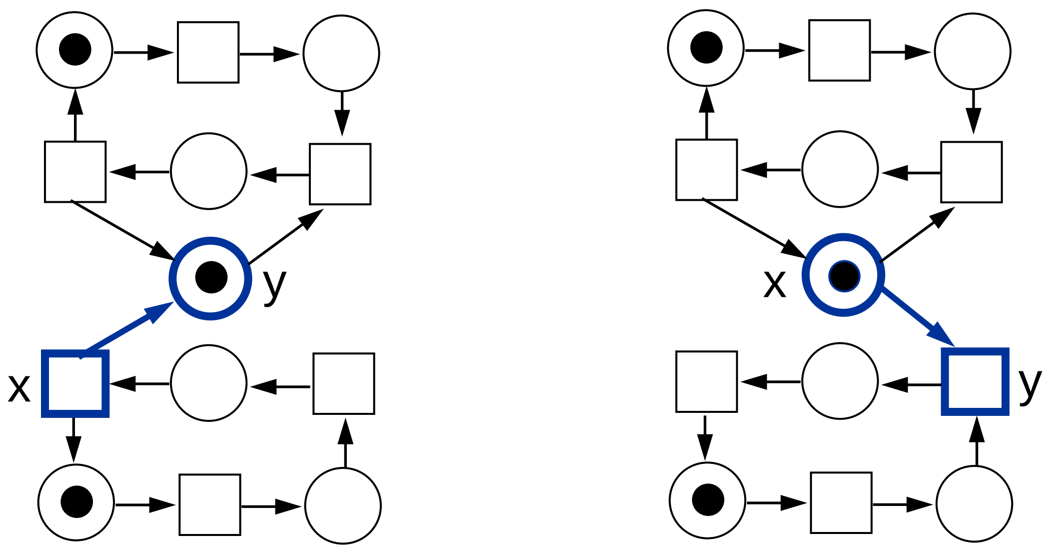
each place has a bound (maximal number of tokens)



live and bounded



Theorem: each connected live and bounded Petri net is strongly connected



Lemma: if a net is connected but not strongly connected then for some arc (*x*,*y*) there is no directed path from *y* to *x*

Corollary: if, in a connected net, for each arc (*x,y*) there is a path from *y* to *x*, then the net is strongly connected

Theorem: each connected live and bounded Petri net is strongly connected

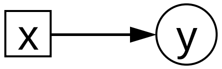
Proof: Consider a live and bounded connected net and an arbitrary arc (x,y).

We will show that there is a path from y to x.

Theorem: each connected live and bounded Petri net is strongly connected

Proof: Consider a live and bounded connected net and an arbitrary arc (*x*,*y*).

Case 1: *x* is a transition and *y* is a place.



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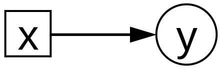
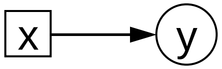


Let *b* be the bound of *y* (exists, because the net is bounded).

Theorem: each connected live and bounded Petri net is strongly connected

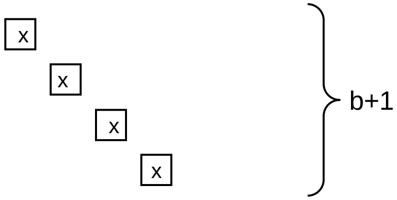
Proof: Consider a live and bounded connected net and an arbitrary arc (x,y).

Case 1: x is a transition and y is a place.



Let b be the bound of y (exists, because the net is bounded).

Assume an occurrence net with $b + 1$ occurrences of the transition x.
(exists, because the net is live).



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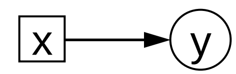

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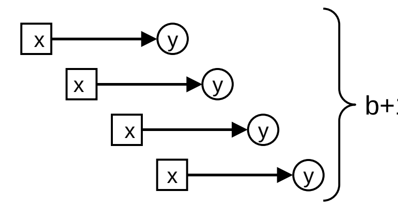
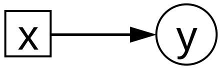


Since postsets of the occurrences of x are respected,
each occurrence of x has an occurrence of y in its postset.

Theorem: each connected live and bounded Petri net is strongly connected

Proof: Consider a live and bounded connected net and an arbitrary arc (*x*,*y*).

Case 1: *x* is a transition and y is a place.



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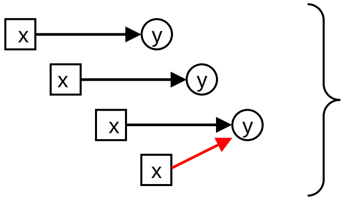


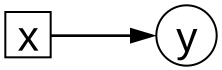
Since postsets of the occurrences of *x* are respected, each occurrence of *x* has an occurrence of *y* in its postset.

Since places in occurrence nets are not branched, all these occurrences of *y* are distinct.

Theorem: each connected live and bounded Petri net is strongly connected

Proof: Consider a live and bounded connected net and an arbitrary arc (x,y).

Case 1: x is a transition and y is a place.



Let b be the bound of y (exists, because the net is bounded).
Assume an occurrence net with b + 1 occurrences of the transition x.
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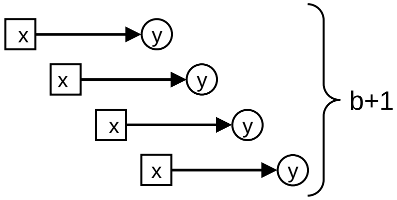


Since postsets of the occurrences of x are respected,
each occurrence of x has an occurrence of y in its postset.

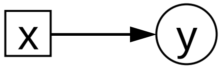
Since places in occurrence nets are not branched,
all these occurrences of y are distinct.

Since b is its bound, the place y never carries more than b tokens.
Hence no co-set contains all b+1 occurrences of y.

Theorem: each connected live and bounded Petri net is strongly connected

Proof: Consider a live and bounded connected net and an arbitrary arc (*x*,*y*).

Case 1: *x* is a transition and *y* is a place.



Let *b* be the bound of y (exists, because the net is bounded).
Assume an occurrence net with *b* + 1 occurrences of the transition *x*.
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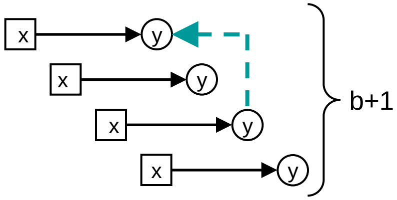

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Since places in occurrence nets are not branched,
all these occurrences of *y* are distinct.

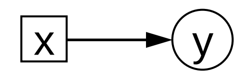
Since *b* is its bound, the place *y* never carries more than *b* tokens.
Hence no co-set contains all *b*+1 occurrences of *y*.

So at least two of these occurrences are connected by a path.

Theorem: each connected live and bounded Petri net is strongly connected

Proof: Consider a live and bounded connected net and an arbitrary arc (x,y).

Case 1: x is a transition and y is a place.



Let b be the bound of y (exists, because the net is bounded).
Assume an occurrence net with b + 1 occurrences of the transition x.
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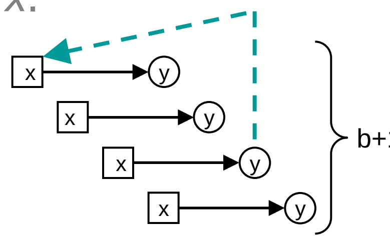

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Since b is its bound, the place y never carries more than b tokens.
Hence no co-set contains all b+1 occurrences of y.

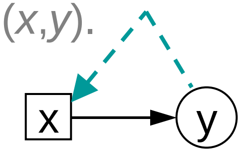
So at least two of these occurrences are connected by a path.

Again since places in occurrence nets are not branched,
this path goes through an occurrence of x.

So there is a path from an occurrence of y to an occurrence of x.

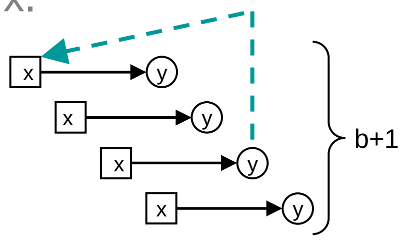
Theorem: each connected live and bounded Petri net is strongly connected

Proof: Consider a live and bounded connected net and an arbitrary arc (*x*,*y*).



Case 1: *x* is a transition and *y* is a place.

Let *b* be the bound of *y* (exists, because the net is bounded).
Assume an occurrence net with *b* + 1 occurrences of the transition x.
(exists, because the net is live).



Since postsets of the occurrences of *x* are respected,
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Since places in occurrence nets are not branched,
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Since *b* is its bound, the place *y* never carries more than *b* tokens.
Hence no co-set contains all *b*+1 occurrences of *y*.

So at least two of these occurrences are connected by a path.

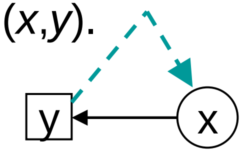
Again since places in occurrence nets are not branched,
this path goes through an occurrence of *x*.

So there is a path from an occurrence of *y* to an occurrence of *x*.

Since paths are mapped to paths, there is a path from *y* to *x*.

Theorem: each connected live and bounded Petri net is strongly connected

Proof: Consider a live and bounded connected net and an arbitrary arc (*x*,*y*).

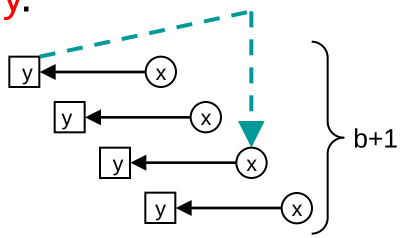


Case 2: *x* is a place and y is a transition.

Let *b* be the bound of x (exists, because the net is bounded).

Assume an occurrence net with *b* + 1 occurrences of the transition y.

(exists, because the net is live).



Since presets of the occurrences of *y* are respected,
each occurrence of *y* has an occurrence of *x* in its preset.

Since places in occurrence nets are not branched,
all these occurrences of *x* are distinct.

Since *b* is its bound, the place *x* never carries more than *b* tokens.
Hence no co-set contains all b+1 occurrences of *x*.

So at least two of these occurrences are connected by a path.

Again since places in occurrence nets are not branched,
this path goes through an occurrence of *y*.

So there is a path from an occurrence of *y* to an occurrence of *x*.

Since paths are mapped to paths, there is a path from *y* to *x*.

PART II:

Process Model Synthesis From Partial Orders (VIPtool)

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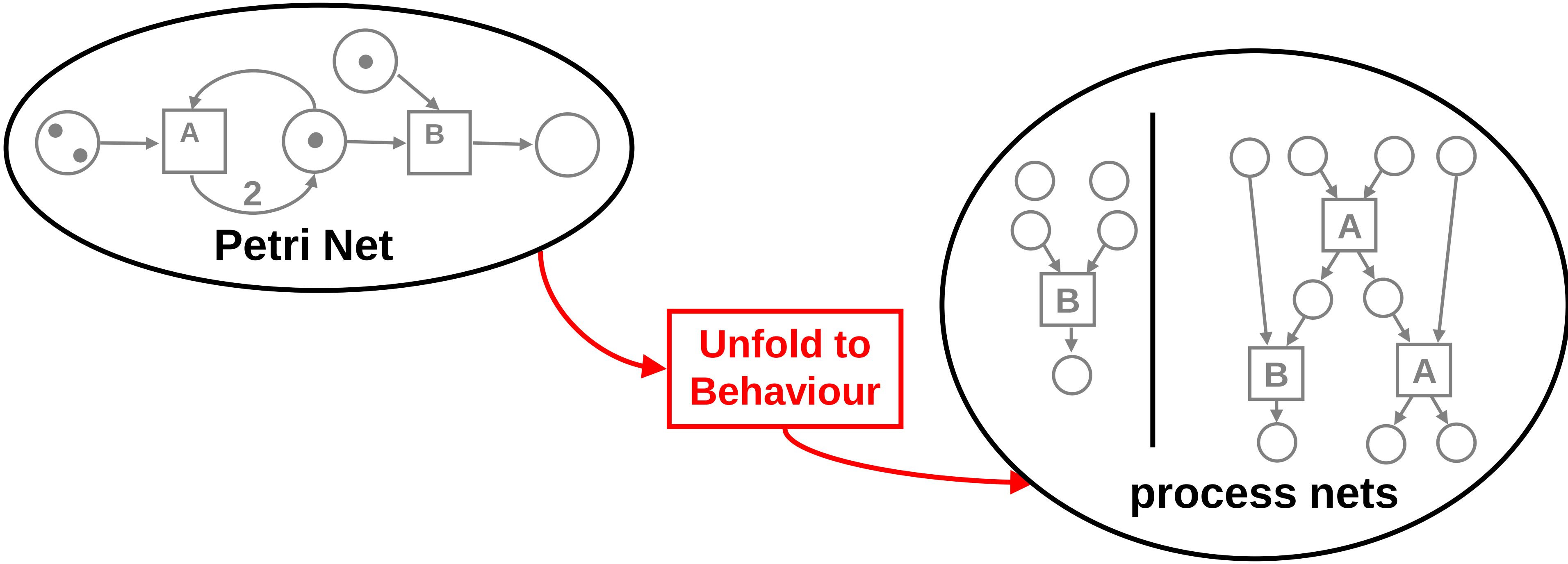
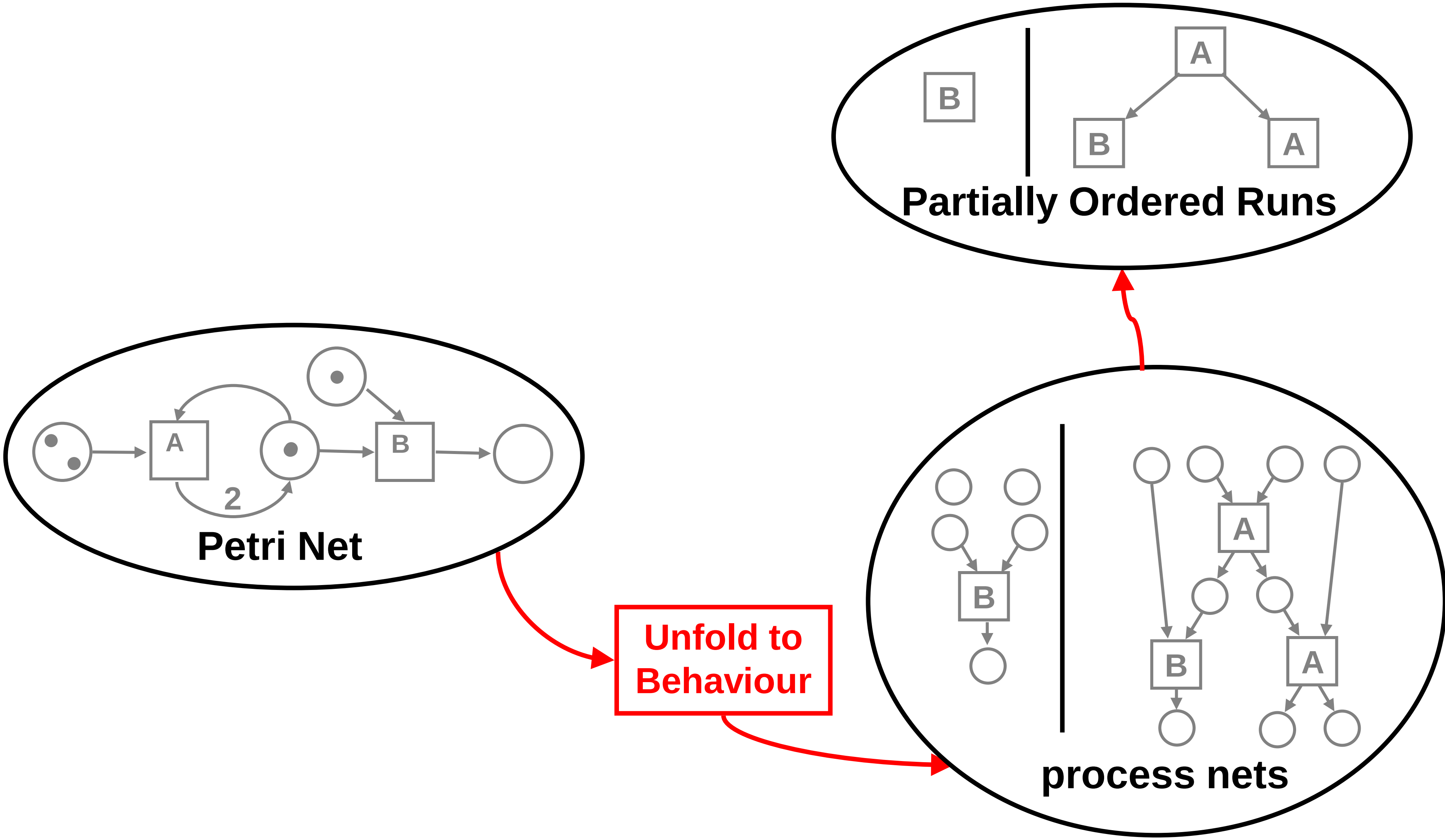
Process Model Synthesis From Partial Orders (VIPtool)

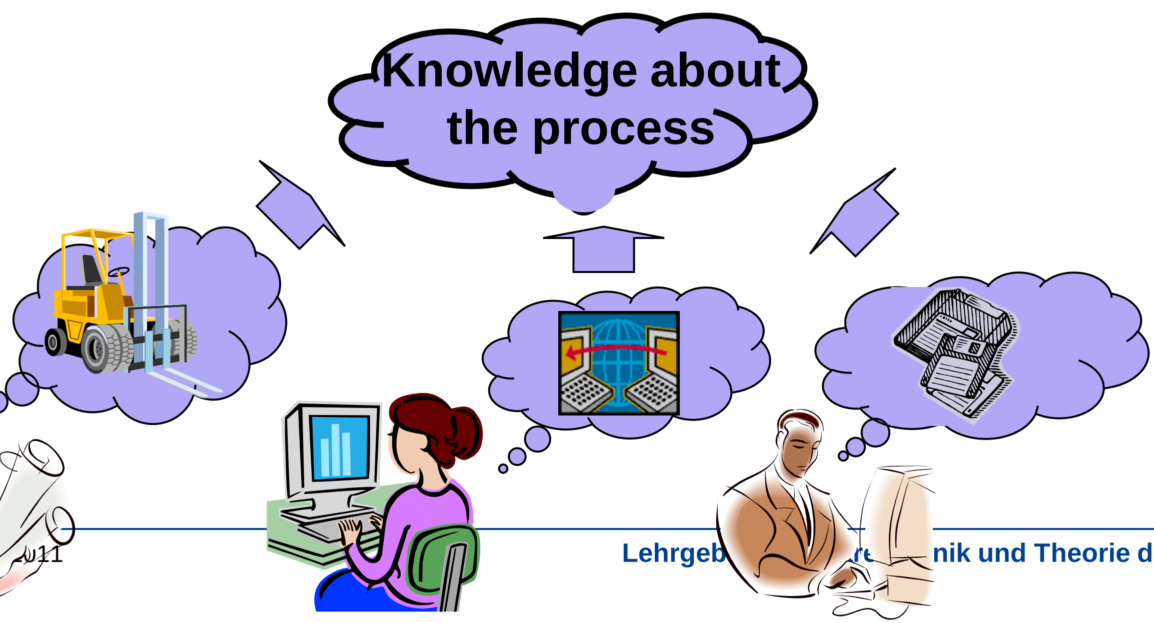
VIPtool was originally created in 1996 -1998 by my group and the group of Andreas Oberweis, Institute AIFB, University of Karlsruhe (Carl-Adam-Petri award !!)

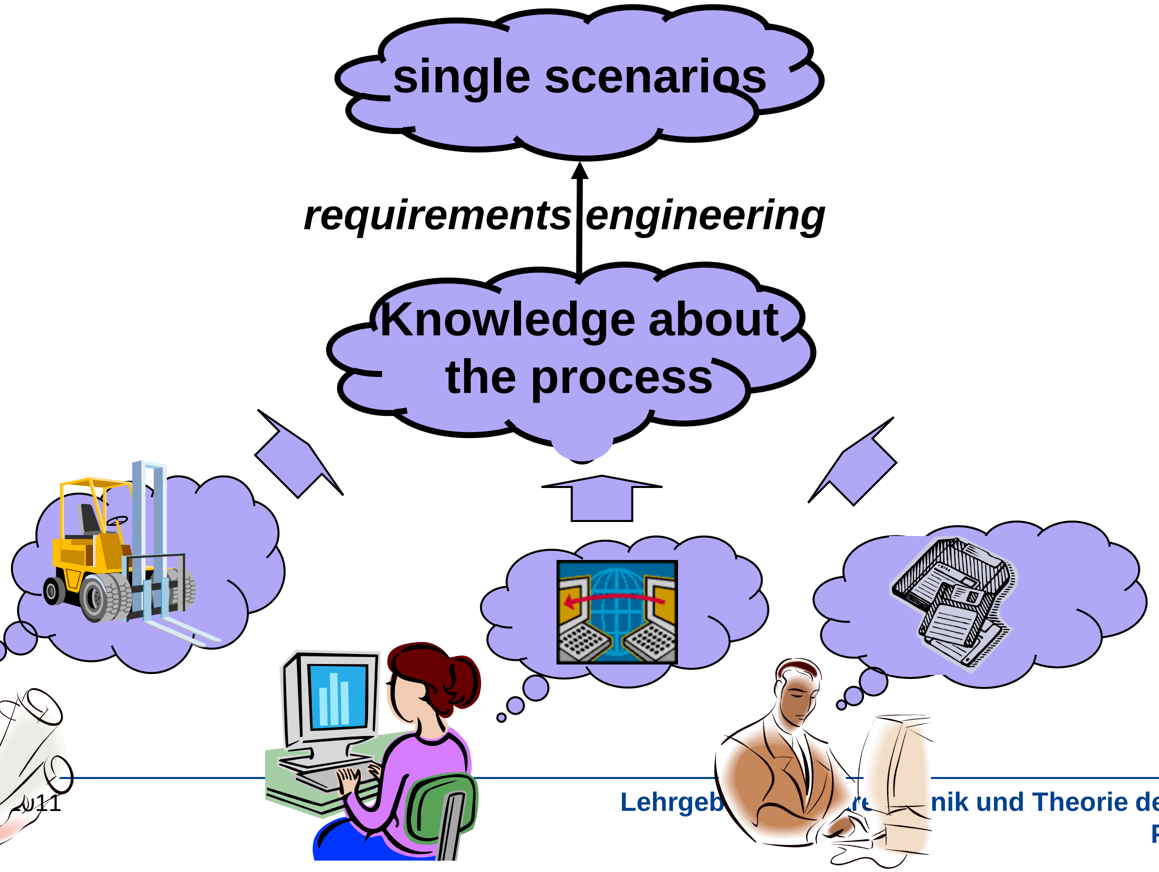

A
B
2
Petri Net
Unfold to
Behaviour
B
B
A
A
process nets

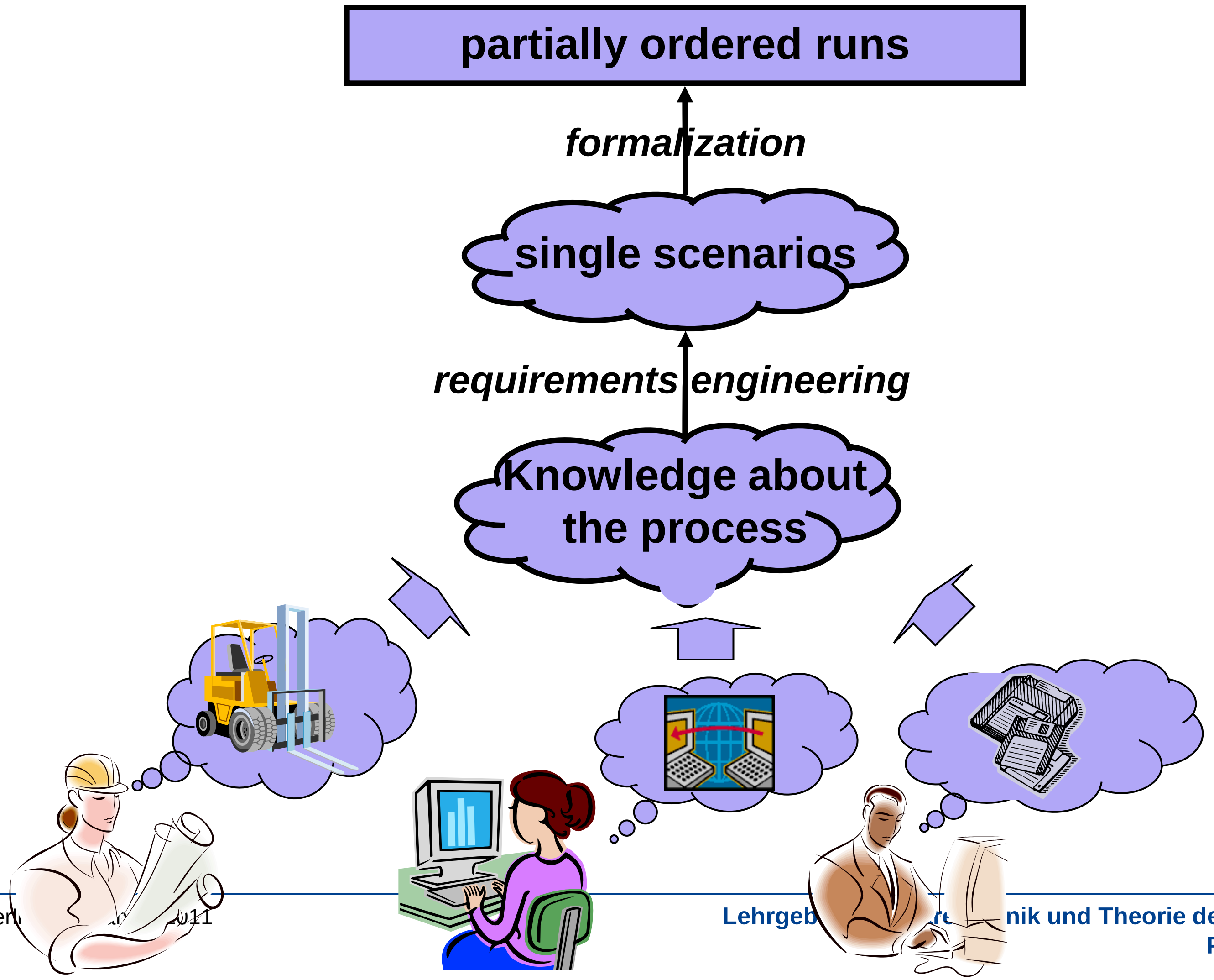

B
A
B
A
Partially Ordered Runs
A
B
2
Petri Net
Unfold to Behaviour
B
A
B
A
process nets

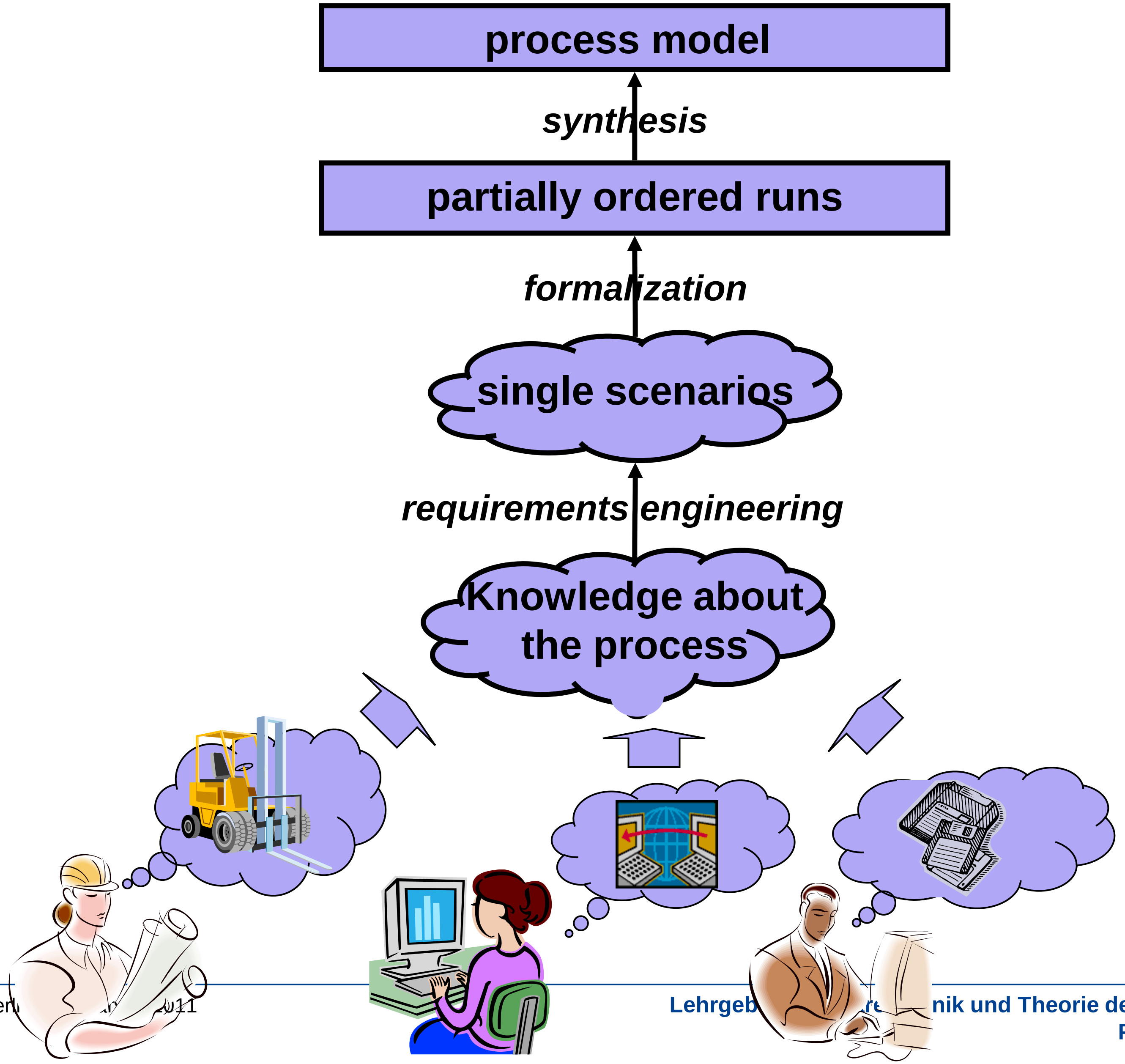
Initial Situation:

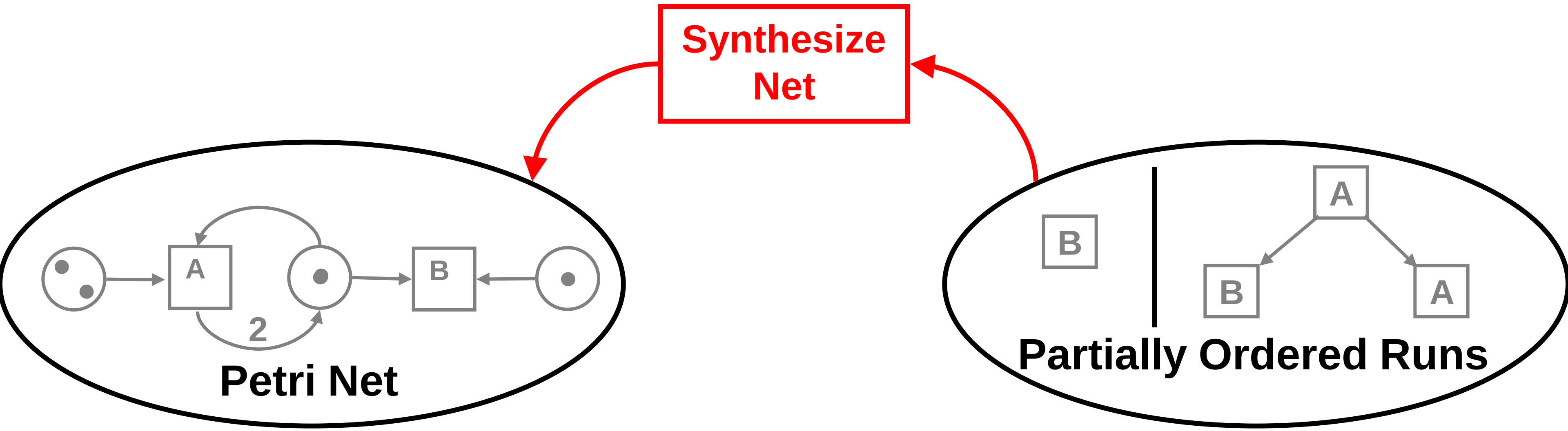
Knowledge about a process is distributed in several peoples‘ mind in an informal environment

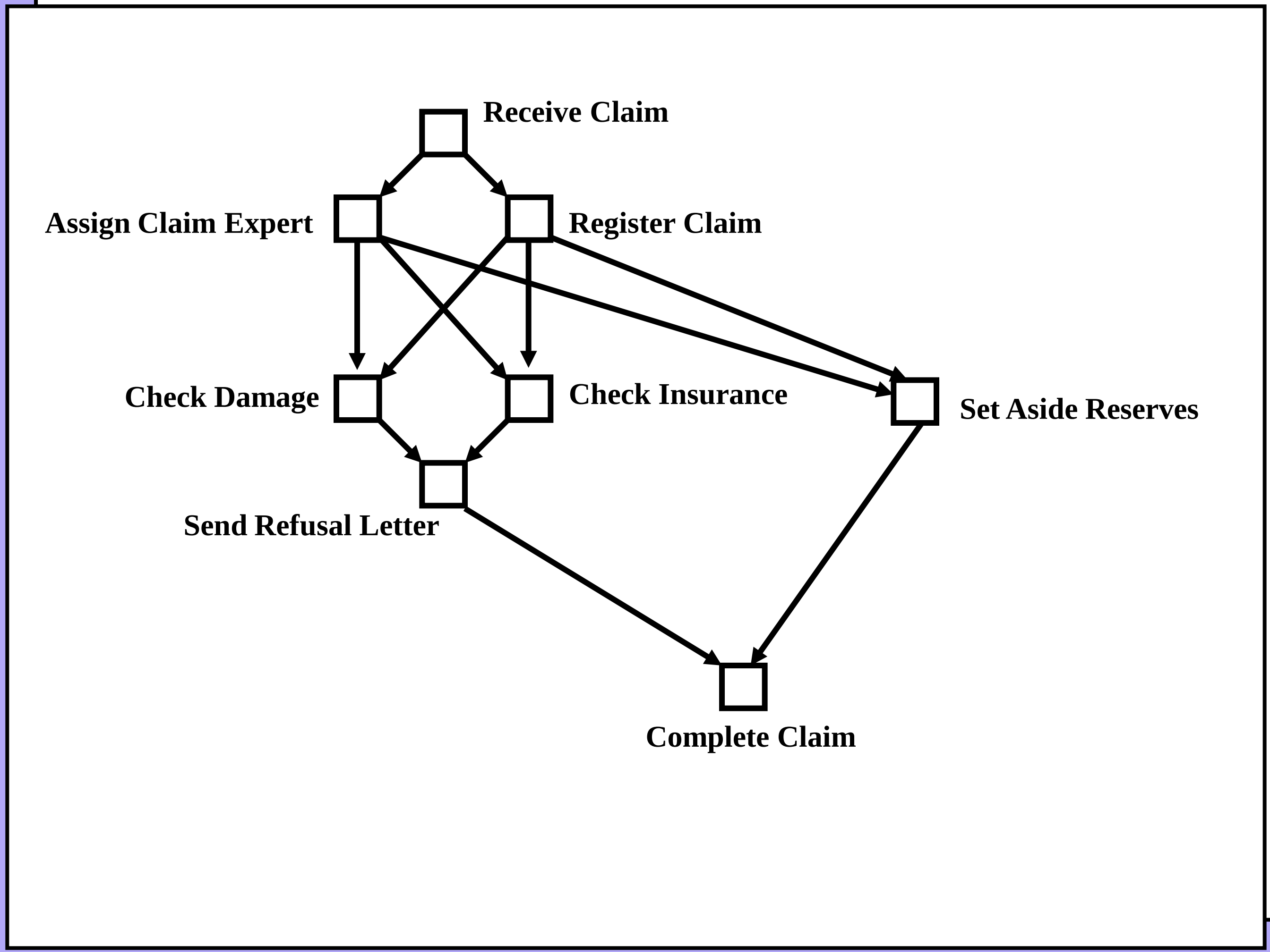



single scenarios
requirements engineering
Knowledge about the process

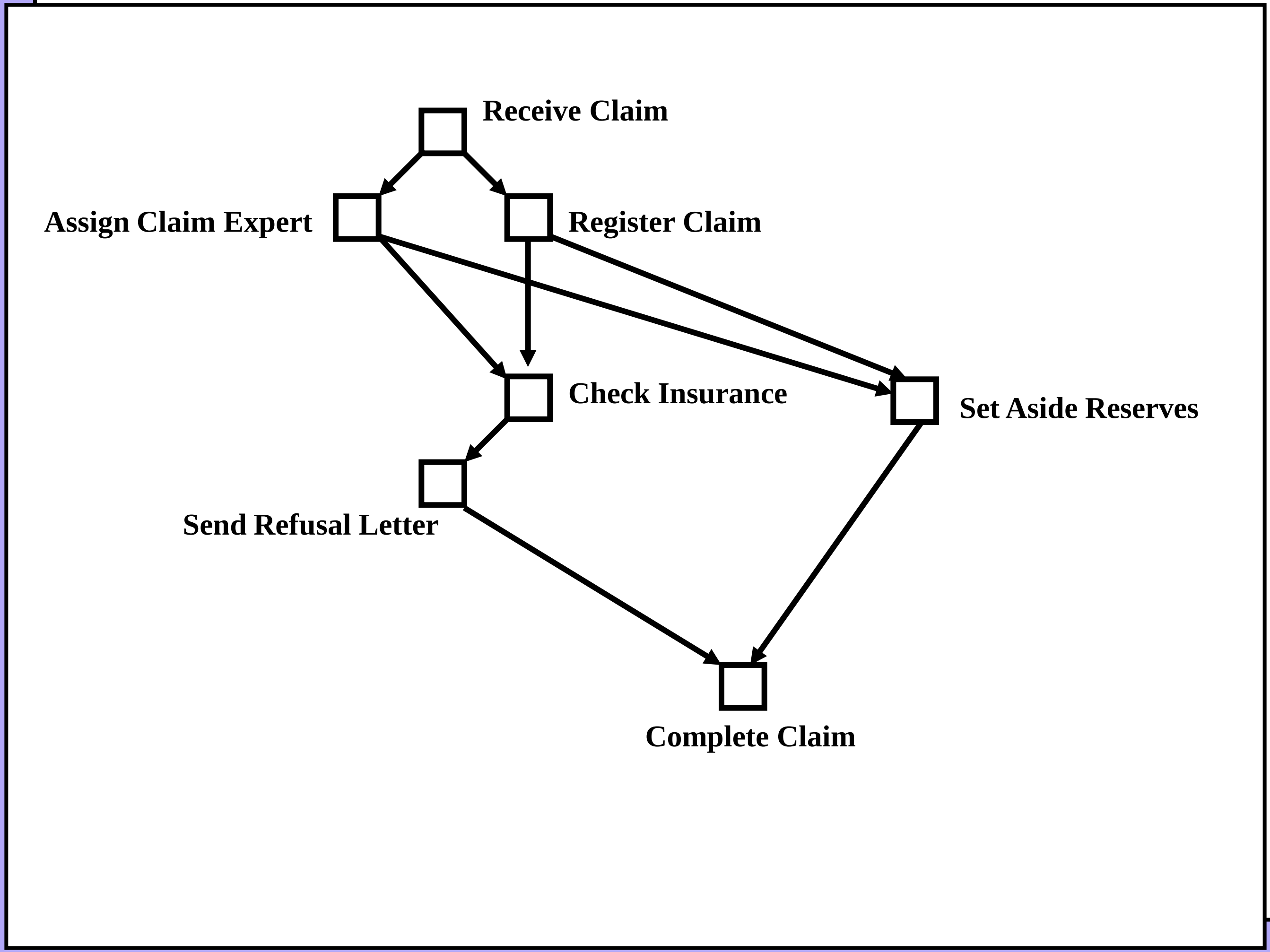

partially ordered runs
formalization
single scenarios
requirements engineering
Knowledge about the process


process model
synthesis
partially ordered runs
formalization
single scenarios
requirements engineering
Knowledge about the process

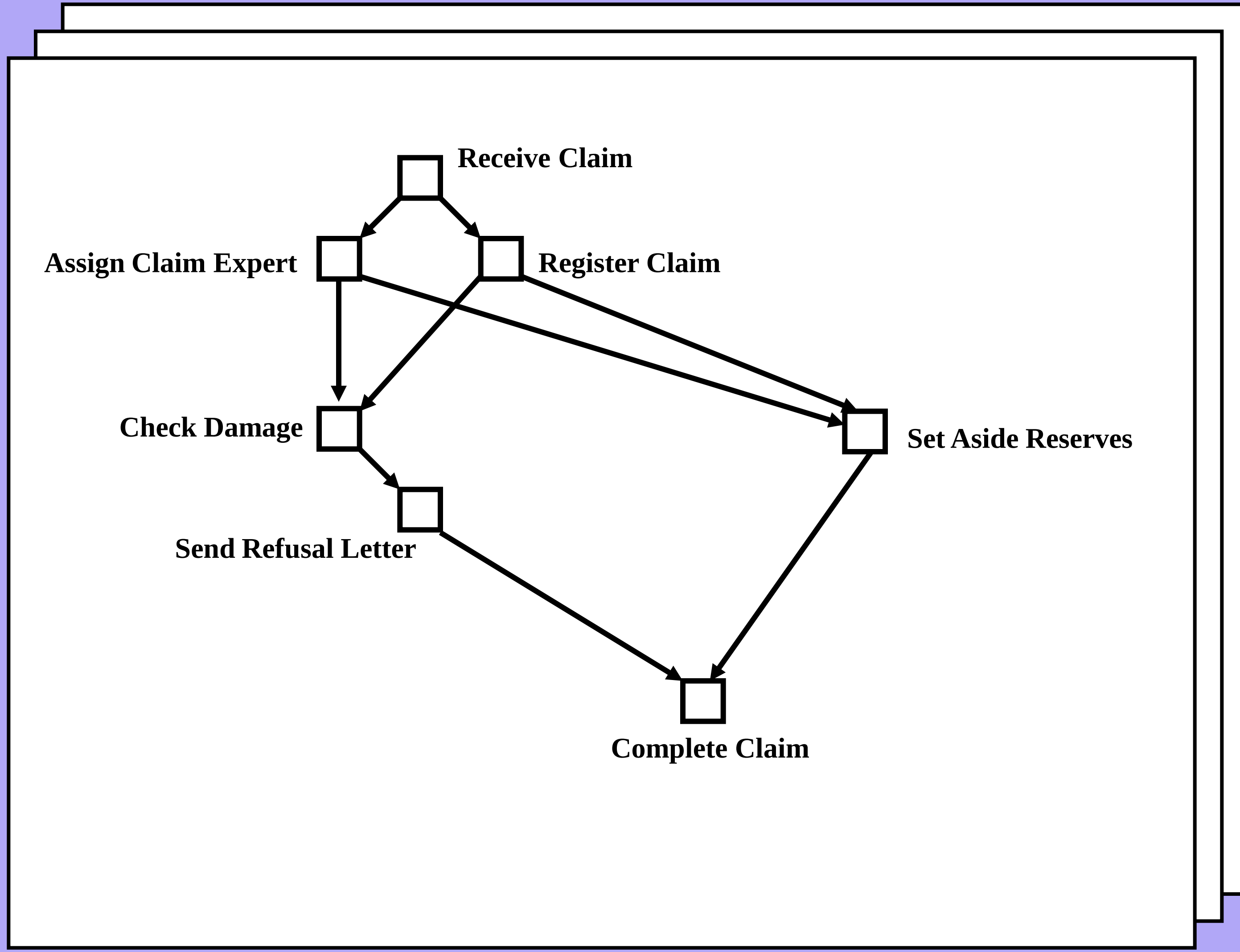

Synthesize
Net
A
B
2
Petri Net
B
A
B
A
Partially Ordered Runs



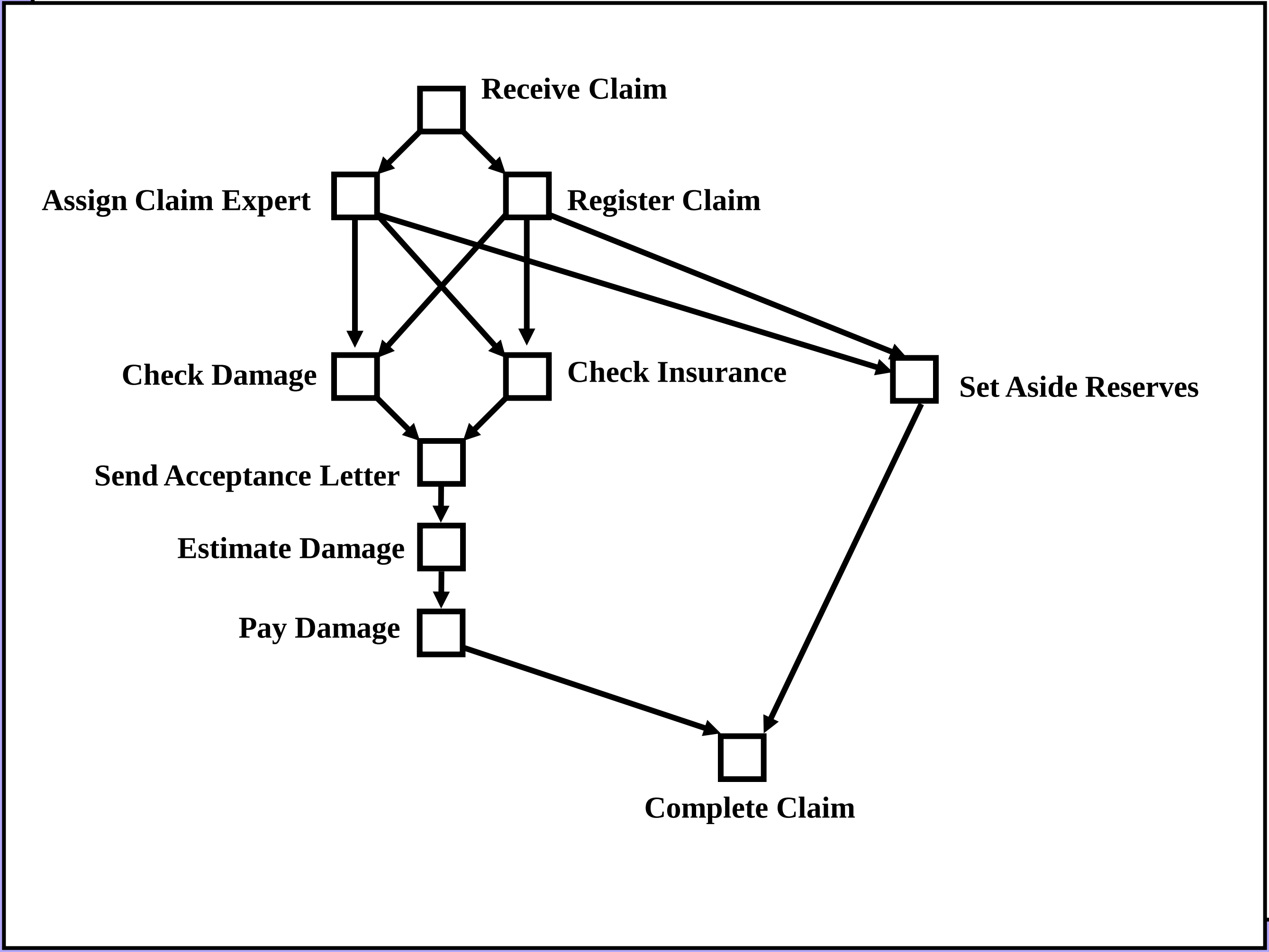
partially ordered runs



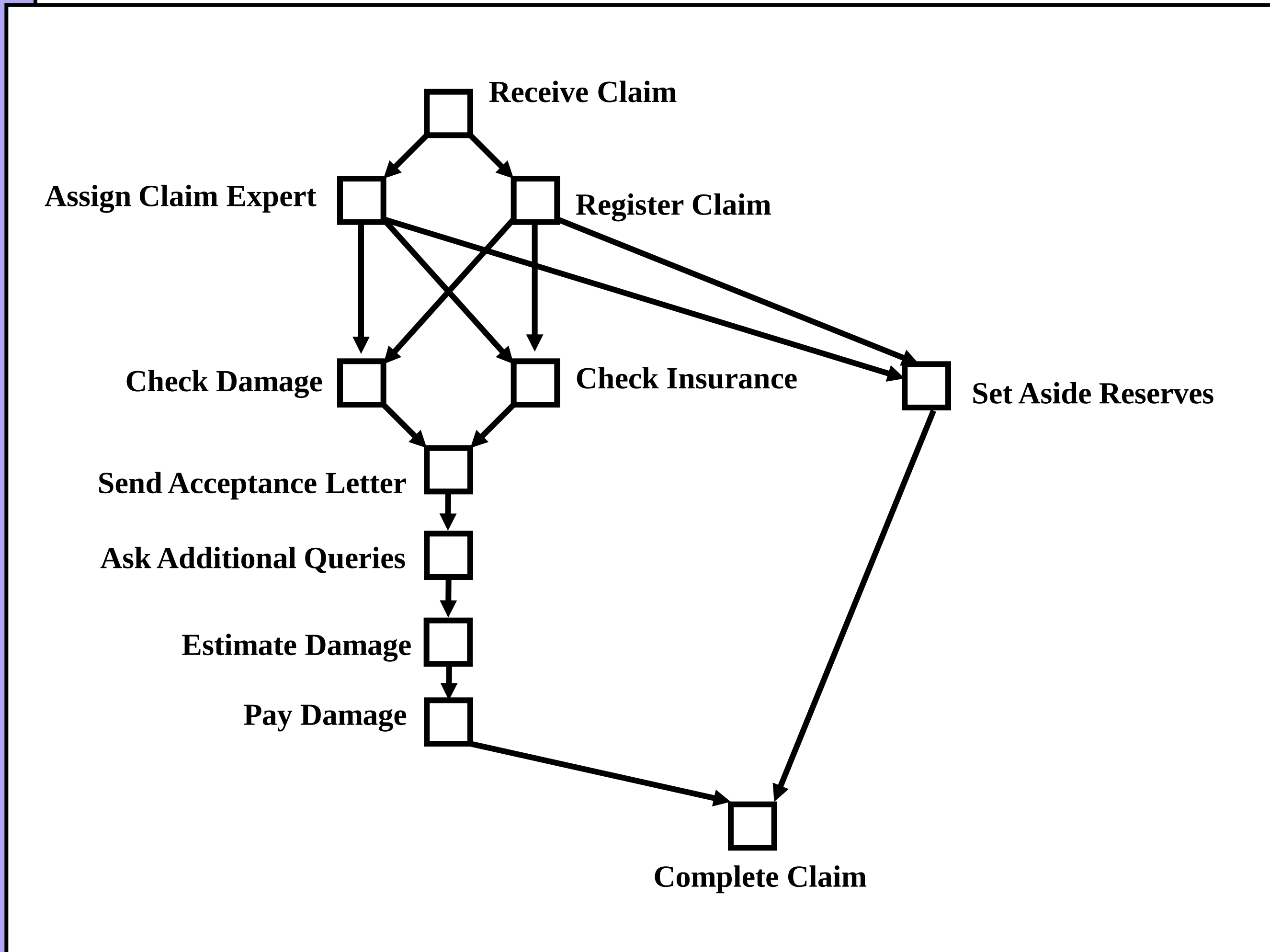
partially ordered runs



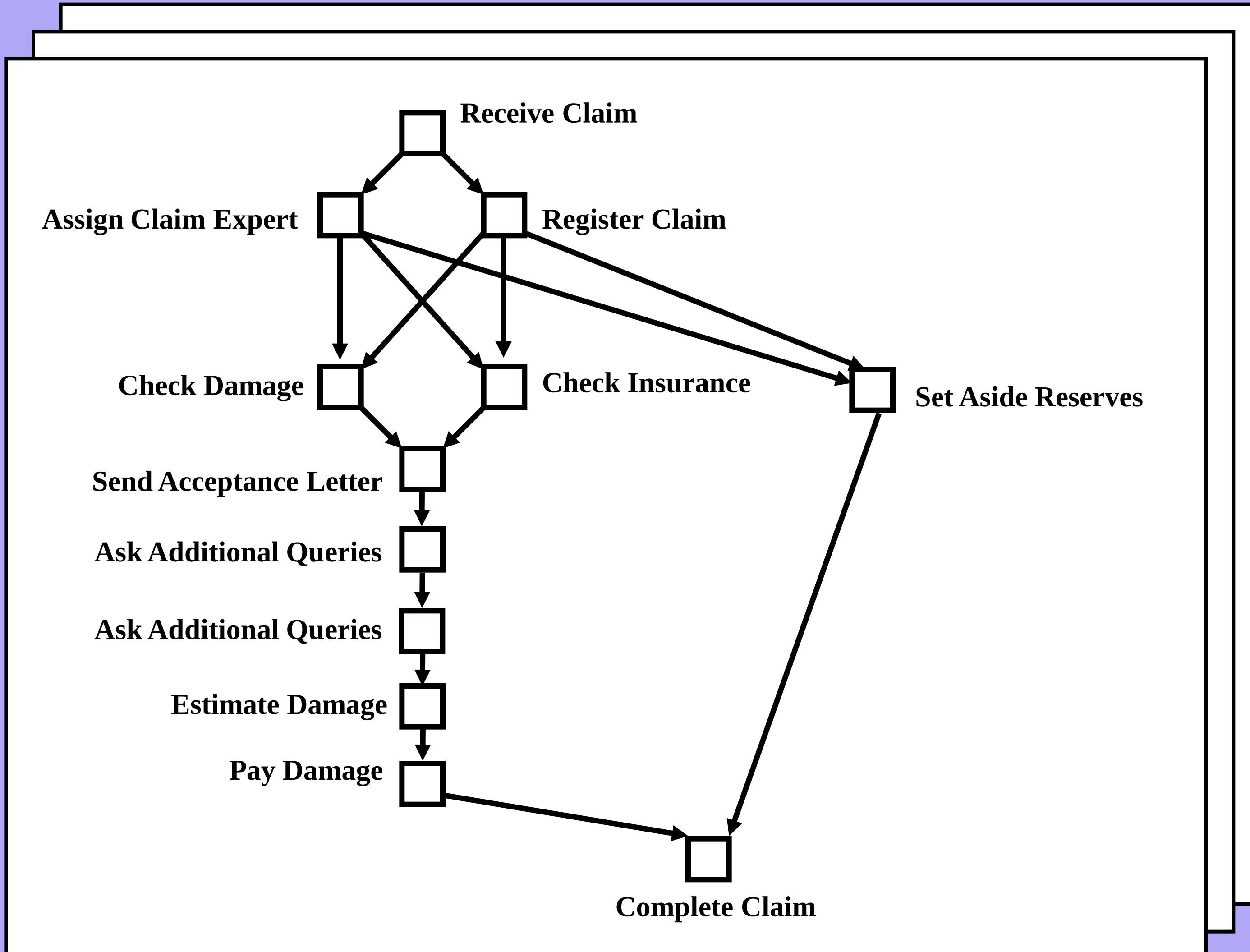
partially ordered runs



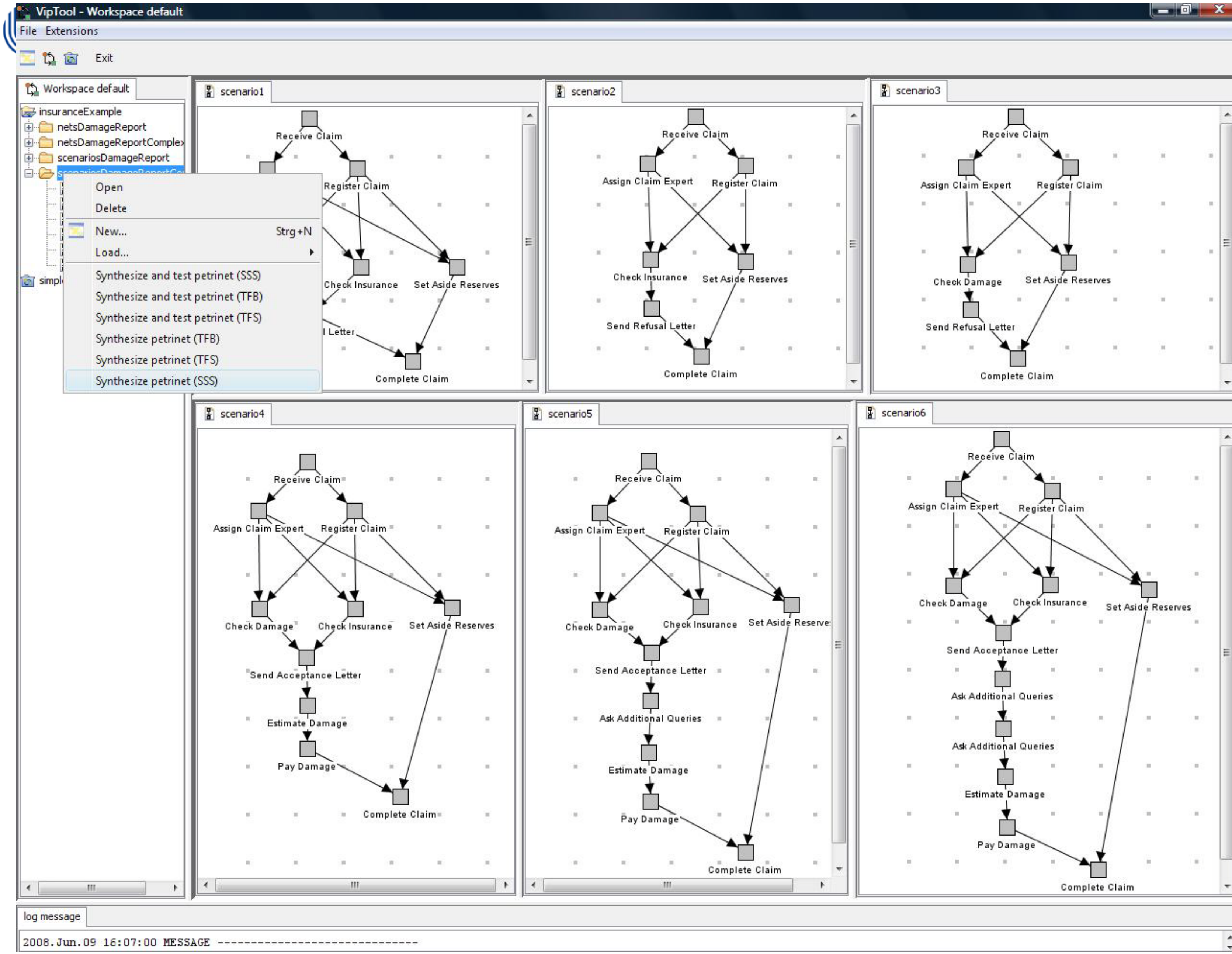
partially ordered runs

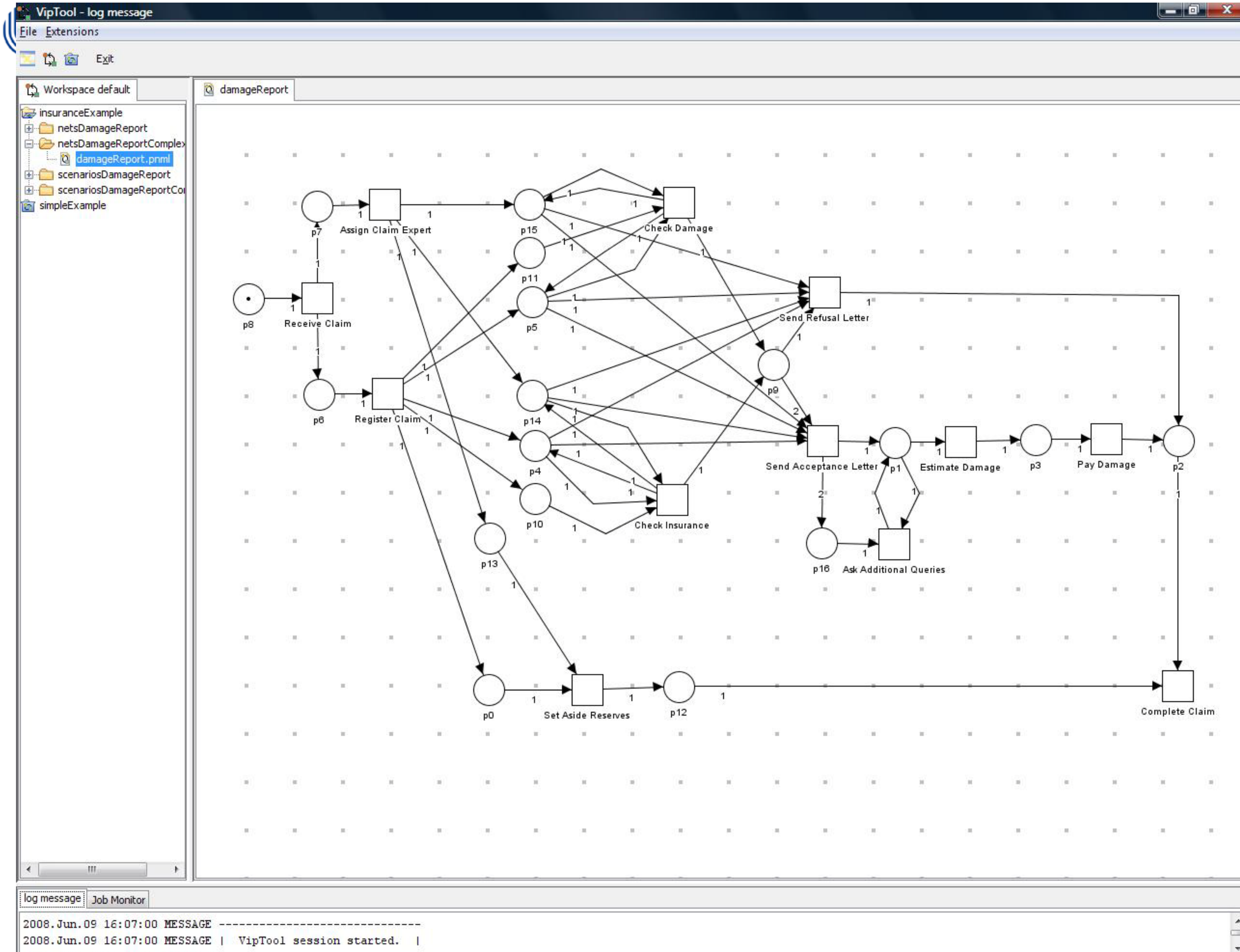


partially ordered runs



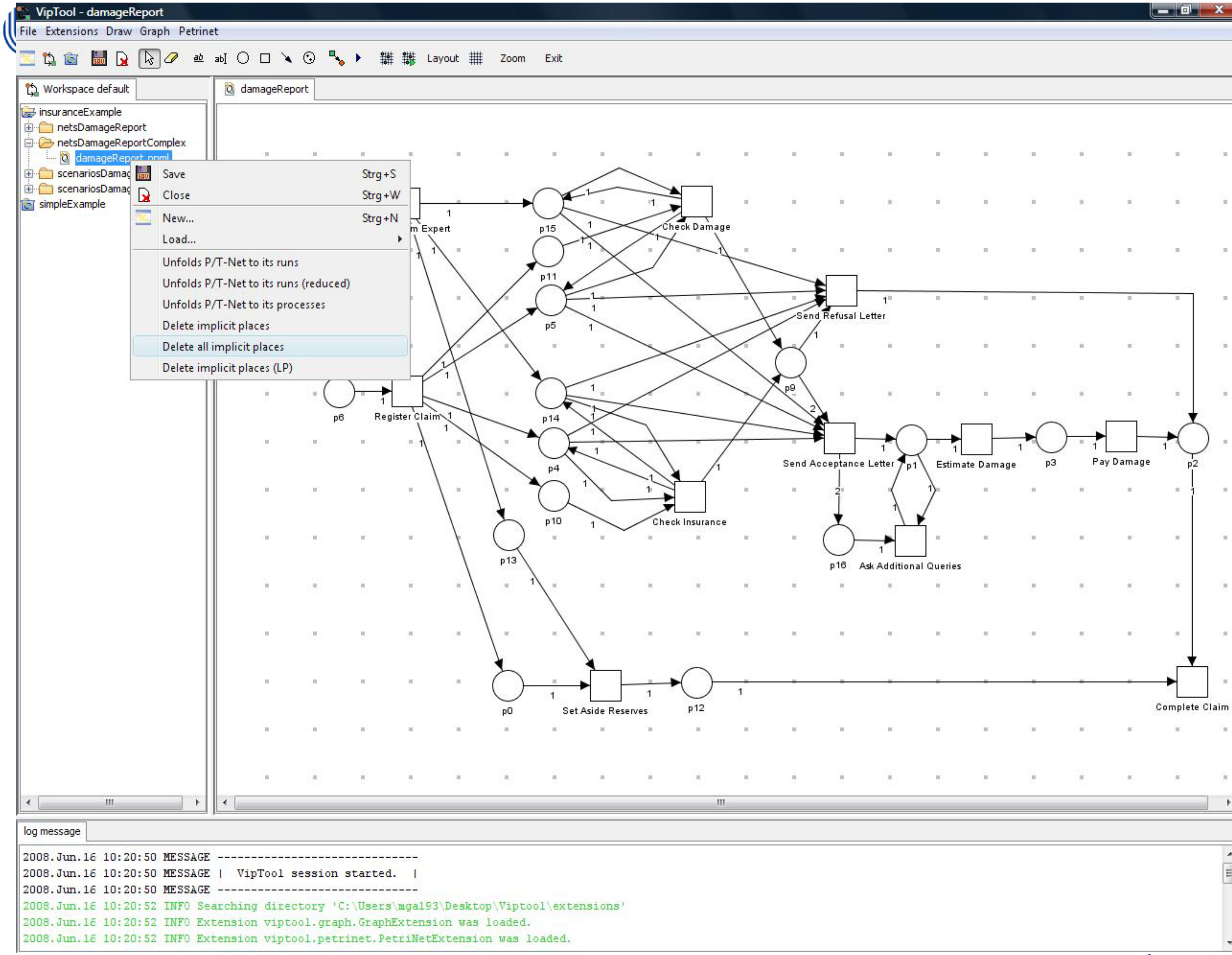
partially ordered runs

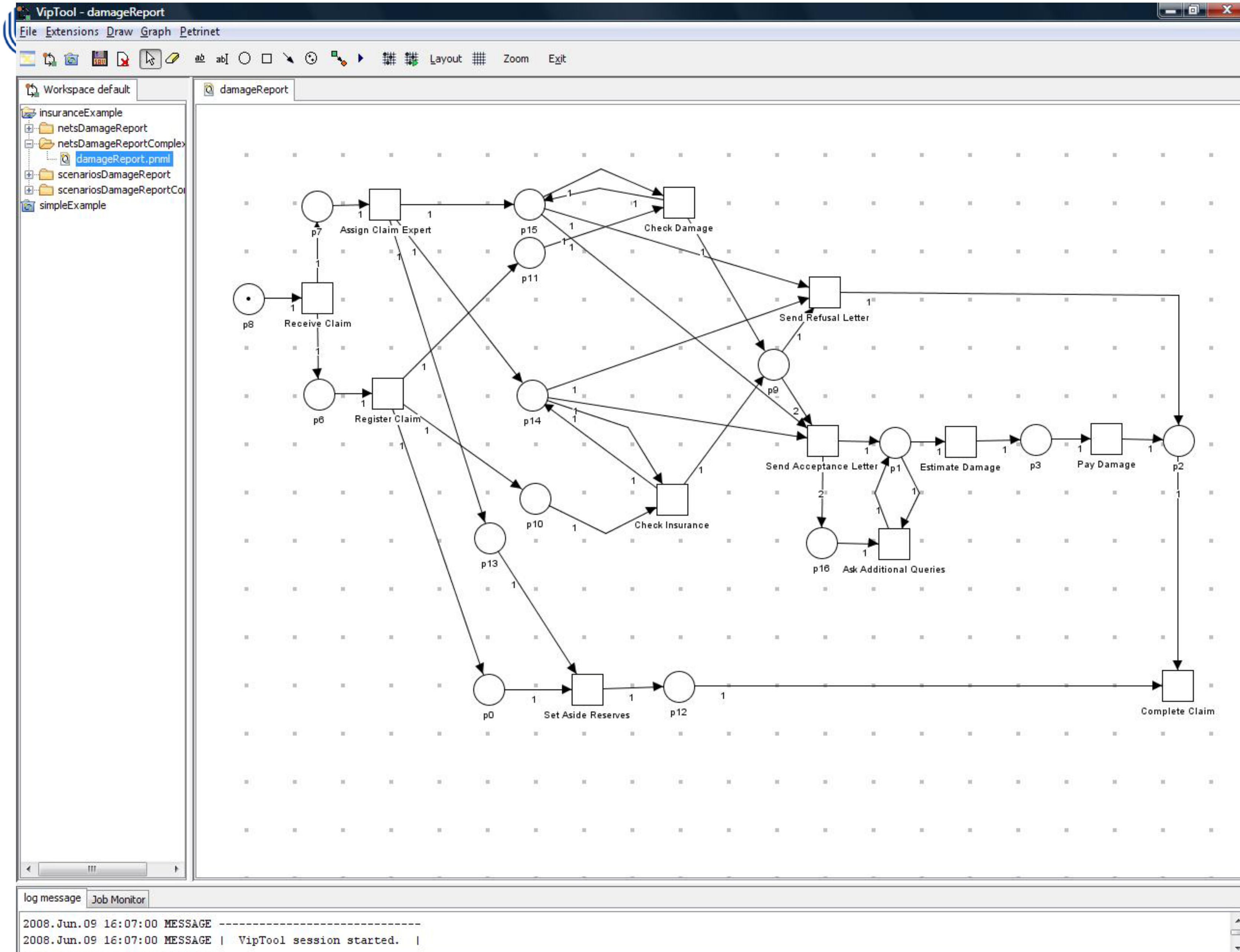

VipTool - Workspace default
File
Extensions
Exit
Workspace default
insuranceExample
netsDamageReport
netsDamageReportComplex
scenariosDamageReport
Open
Delete
New...
Strg+N
Load...
Synthesize and test petrinet (SSS)
Synthesize and test petrinet (TFB)
Synthesize and test petrinet (TFS)
Synthesize petrinet (TFB)
Synthesize petrinet (TFS)
Synthesize petrinet (SSS)
scenario1
scenario2
scenario3
scenario4
scenario5
scenario6
Receive Claim
Assign Claim Expert
Register Claim
Check Damage
Check Insurance
Set Aside Reserves
Send Refusal Letter
Send Acceptance Letter
Ask Additional Queries
Estimate Damage
Pay Damage
Complete Claim
log message
2008.Jun.09 16:07:00 MESSAGE -----------------------------

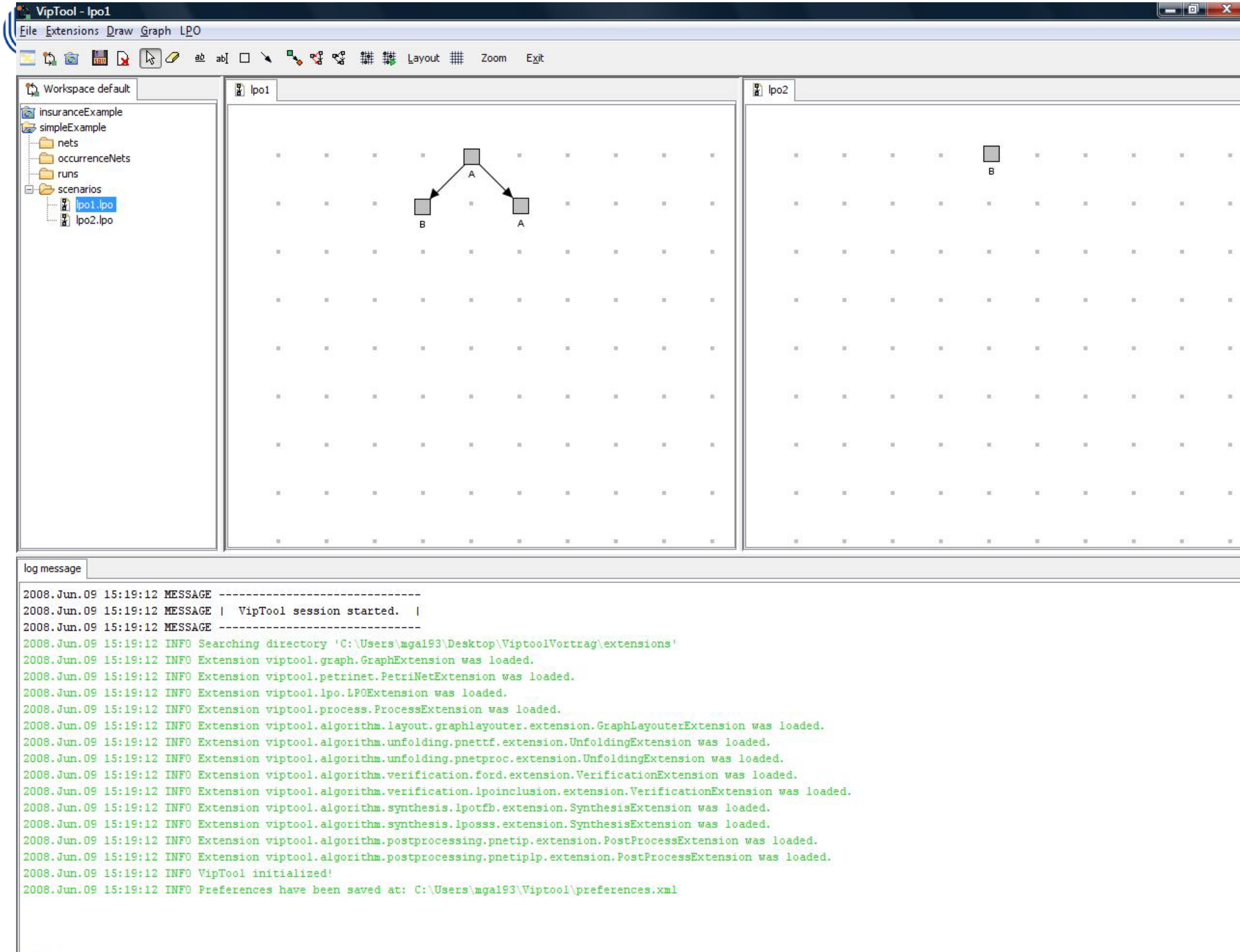

VipTool - log message
File Extensions
Exit
Workspace default
insuranceExample
netsDamageReport
netsDamageReportComplex
damageReport.pnml
scenariosDamageReport
simpleExample
damageReport
p8
Receive Claim
p7
p6
Assign Claim Expert
Register Claim
p15
p11
p5
p14
p4
p10
p13
p0
Check Damage
Check Insurance
Send Refusal Letter
Send Acceptance Letter
p9
p1
p16
Ask Additional Queries
Estimate Damage
p3
Pay Damage
p2
Set Aside Reserves
p12
Complete Claim
log message
Job Monitor
2008.Jun.09 16:07:00 MESSAGE ------------------------------
2008.Jun.09 16:07:00 MESSAGE | VipTool session started. |

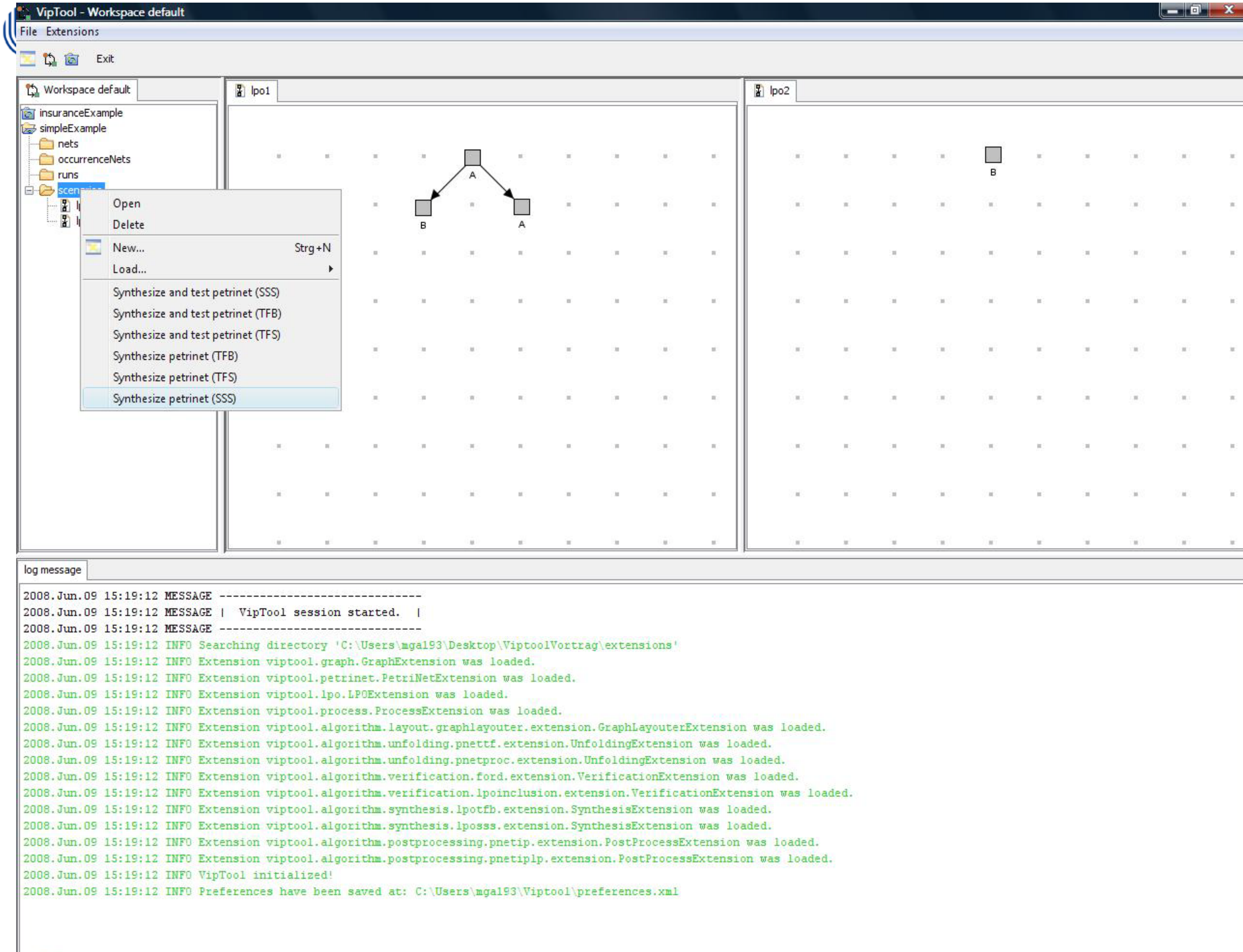
tik

erung


VipTool - damageReport
File Extensions Draw Graph Petrinet
Layout
Zoom
Exit
Workspace default
damageReport
insuranceExample
netsDamageReport
netsDamageReportComplex
damageReport.pnml
simpleExample
Save Strg+S
Close Strg+W
New... Strg+N
Load...
Unfolds P/T-Net to its runs
Unfolds P/T-Net to its runs (reduced)
Unfolds P/T-Net to its processes
Delete implicit places
Delete all implicit places
Delete implicit places (LP)
Check Damage
Send Refusal Letter
Register Claim
Send Acceptance Letter
Estimate Damage
Pay Damage
Check Insurance
Ask Additional Queries
Set Aside Reserves
Complete Claim
log message
2008.Jun.16 10:20:50 MESSAGE -----------------------------
2008.Jun.16 10:20:50 MESSAGE | VipTool session started. |
2008.Jun.16 10:20:50 MESSAGE -----------------------------
2008.Jun.16 10:20:52 INFO Searching directory 'C:\Users\mga193\Desktop\Viptool\extensions'
2008.Jun.16 10:20:52 INFO Extension viptool.graph.GraphExtension was loaded.
2008.Jun.16 10:20:52 INFO Extension viptool.petrinet.PetriNetExtension was loaded.


VipTool - damageReport
File Extensions Draw Graph Petrinet
Layout Zoom Exit
Workspace default
insuranceExample
netsDamageReport
netsDamageReportComplex
damageReport.pnml
scenariosDamageReport
scenariosDamageReportCo
simpleExample
damageReport
p7
Assign Claim Expert
p15
Check Damage
p11
p8
Receive Claim
Send Refusal Letter
p9
p6
Register Claim
p14
Send Acceptance Letter
p1
Estimate Damage
p3
Pay Damage
p2
p10
Check Insurance
p16
Ask Additional Queries
p13
p0
Set Aside Reserves
p12
Complete Claim
log message
Job Monitor
2008.Jun.09 16:07:00 MESSAGE ------------------------------
2008.Jun.09 16:07:00 MESSAGE | VipTool session started. |


VipTool - lpo1
File Extensions Draw Graph LPO
Layout
Zoom
Exit
Workspace default
insuranceExample
simpleExample
nets
occurrenceNets
runs
scenarios
lpo1.lpo
lpo2.lpo
lpo1
A
B
A
lpo2
B
log message
2008.Jun.09 15:19:12 MESSAGE ------------------------------
2008.Jun.09 15:19:12 MESSAGE | VipTool session started. |
2008.Jun.09 15:19:12 MESSAGE ------------------------------
2008.Jun.09 15:19:12 INFO Searching directory 'C:\Users\mga193\Desktop\ViptoolVortrag\extensions'
2008.Jun.09 15:19:12 INFO Extension viptool.graph.GraphExtension was loaded.
2008.Jun.09 15:19:12 INFO Extension viptool.petrinet.PetriNetExtension was loaded.
2008.Jun.09 15:19:12 INFO Extension viptool.lpo.LPOExtension was loaded.
2008.Jun.09 15:19:12 INFO Extension viptool.process.ProcessExtension was loaded.
2008.Jun.09 15:19:12 INFO Extension viptool.algorithm.layout.graphlayouter.extension.GraphLayouterExtension was loaded.
2008.Jun.09 15:19:12 INFO Extension viptool.algorithm.unfolding.pnettf.extension.UnfoldingExtension was loaded.
2008.Jun.09 15:19:12 INFO Extension viptool.algorithm.unfolding.pnetproc.extension.UnfoldingExtension was loaded.
2008.Jun.09 15:19:12 INFO Extension viptool.algorithm.verification.ford.extension.VerificationExtension was loaded.
2008.Jun.09 15:19:12 INFO Extension viptool.algorithm.verification.lpoinclusion.extension.VerificationExtension was loaded.
2008.Jun.09 15:19:12 INFO Extension viptool.algorithm.synthesis.lpotfb.extension.SynthesisExtension was loaded.
2008.Jun.09 15:19:12 INFO Extension viptool.algorithm.synthesis.lposss.extension.SynthesisExtension was loaded.
2008.Jun.09 15:19:12 INFO Extension viptool.algorithm.postprocessing.pnetip.extension.PostProcessExtension was loaded.
2008.Jun.09 15:19:12 INFO Extension viptool.algorithm.postprocessing.pnetiplp.extension.PostProcessExtension was loaded.
2008.Jun.09 15:19:12 INFO VipTool initialized!
2008.Jun.09 15:19:12 INFO Preferences have been saved at: C:\Users\mga193\Viptool\preferences.xml


VipTool - Workspace default
File Extensions
Exit
Workspace default
insuranceExample
simpleExample
nets
occurrenceNets
runs
lpo1
lpo2
A
B
A
B
Open
Delete
New... Strg+N
Load...
Synthesize and test petrinet (SSS)
Synthesize and test petrinet (TFB)
Synthesize and test petrinet (TFS)
Synthesize petrinet (TFB)
Synthesize petrinet (TFS)
Synthesize petrinet (SSS)
log message
2008.Jun.09 15:19:12 MESSAGE -----------------------------
2008.Jun.09 15:19:12 MESSAGE | VipTool session started. |
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2008.Jun.09 15:19:12 INFO Extension viptool.process.ProcessExtension was loaded.
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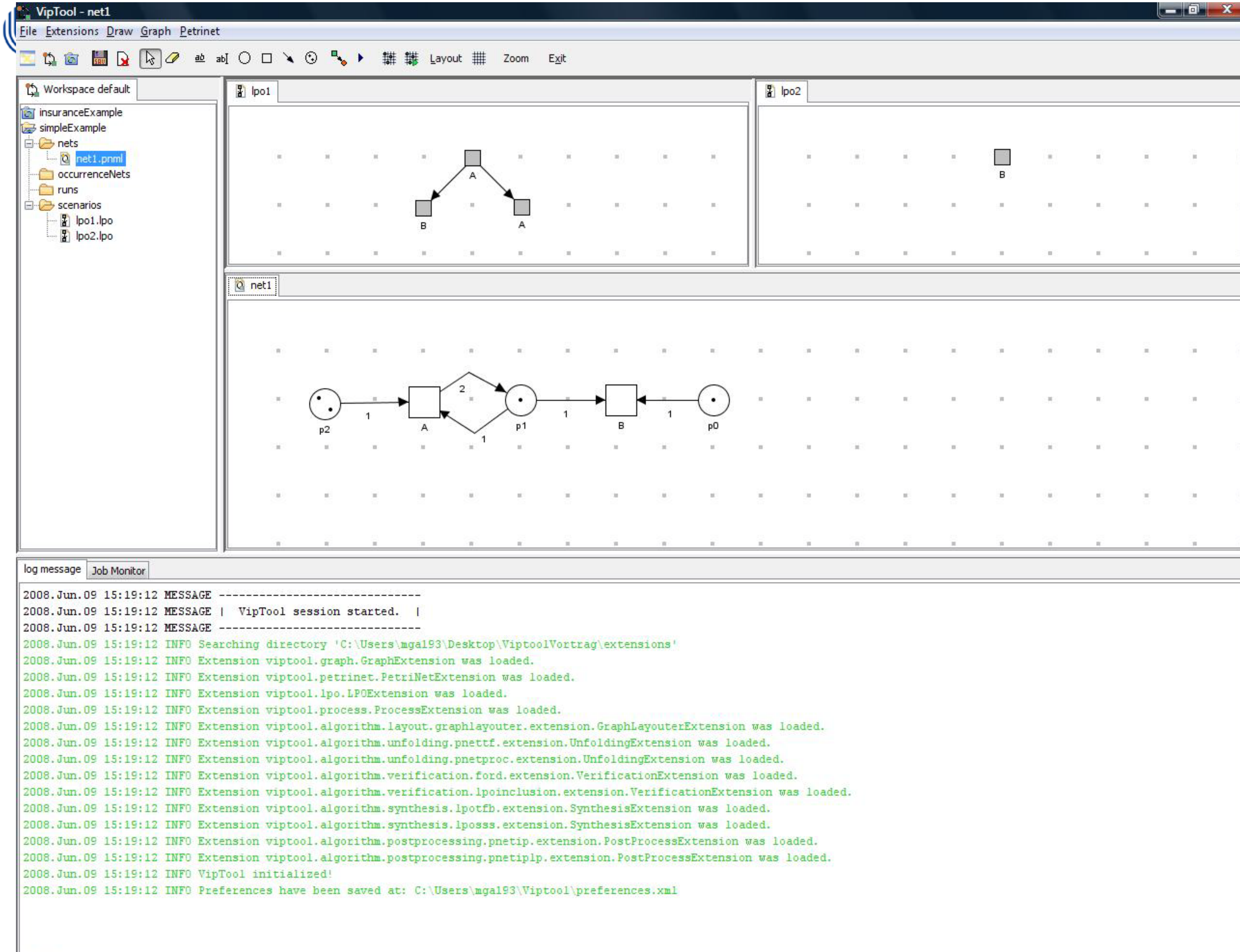
VipTool - net1
File Extensions Draw Graph Petrinet
Layout Zoom Exit
Workspace default
insuranceExample
simpleExample
nets
net1.pnml
occurrenceNets
runs
scenarios
lpo1.lpo
lpo2.lpo
lpo1
A
B
A
lpo2
B
net1
p2
1
A
2
1
p1
1
B
1
p0
log message
Job Monitor
2008.Jun.09 15:19:12 MESSAGE ------------------------------
2008.Jun.09 15:19:12 MESSAGE | VipTool session started. |
2008.Jun.09 15:19:12 MESSAGE ------------------------------
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2008.Jun.09 15:19:12 INFO Extension viptool.algorithm.synthesis.lpotfb.extension.SynthesisExtension was loaded.
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2008.Jun.09 15:19:12 INFO Extension viptool.algorithm.postprocessing.pnetip.extension.PostProcessExtension was loaded.
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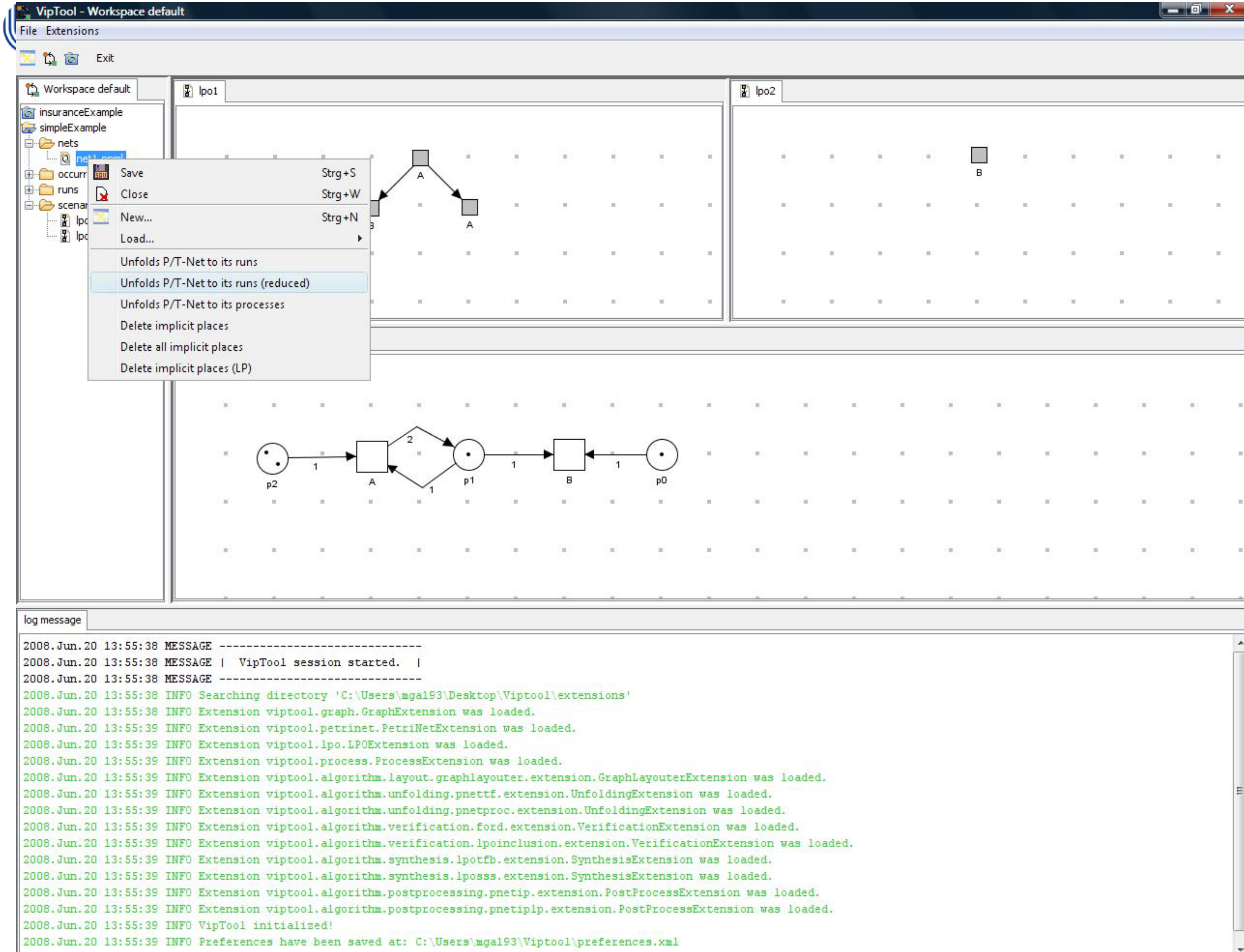
VipTool - Workspace default
File Extensions
Exit
Workspace default
insuranceExample
simpleExample
nets
runs
lpo1
lpo2
Save Strg+S
Close Strg+W
New... Strg+N
Load...
Unfolds P/T-Net to its runs
Unfolds P/T-Net to its runs (reduced)
Unfolds P/T-Net to its processes
Delete implicit places
Delete all implicit places
Delete implicit places (LP)
A
B
p2
p1
p0
log message
2008.Jun.20 13:55:38 MESSAGE -----------------------------
2008.Jun.20 13:55:38 MESSAGE | VipTool session started. |
2008.Jun.20 13:55:38 MESSAGE -----------------------------
2008.Jun.20 13:55:38 INFO Searching directory 'C:\Users\mga193\Desktop\Viptool\extensions'
2008.Jun.20 13:55:38 INFO Extension viptool.graph.GraphExtension was loaded.
2008.Jun.20 13:55:38 INFO Extension viptool.petrinet.PetriNetExtension was loaded.
2008.Jun.20 13:55:39 INFO Extension viptool.lpo.LPOExtension was loaded.
2008.Jun.20 13:55:39 INFO Extension viptool.process.ProcessExtension was loaded.
2008.Jun.20 13:55:39 INFO Extension viptool.algorithm.layout.graphlayouter.extension.GraphLayouterExtension was loaded.
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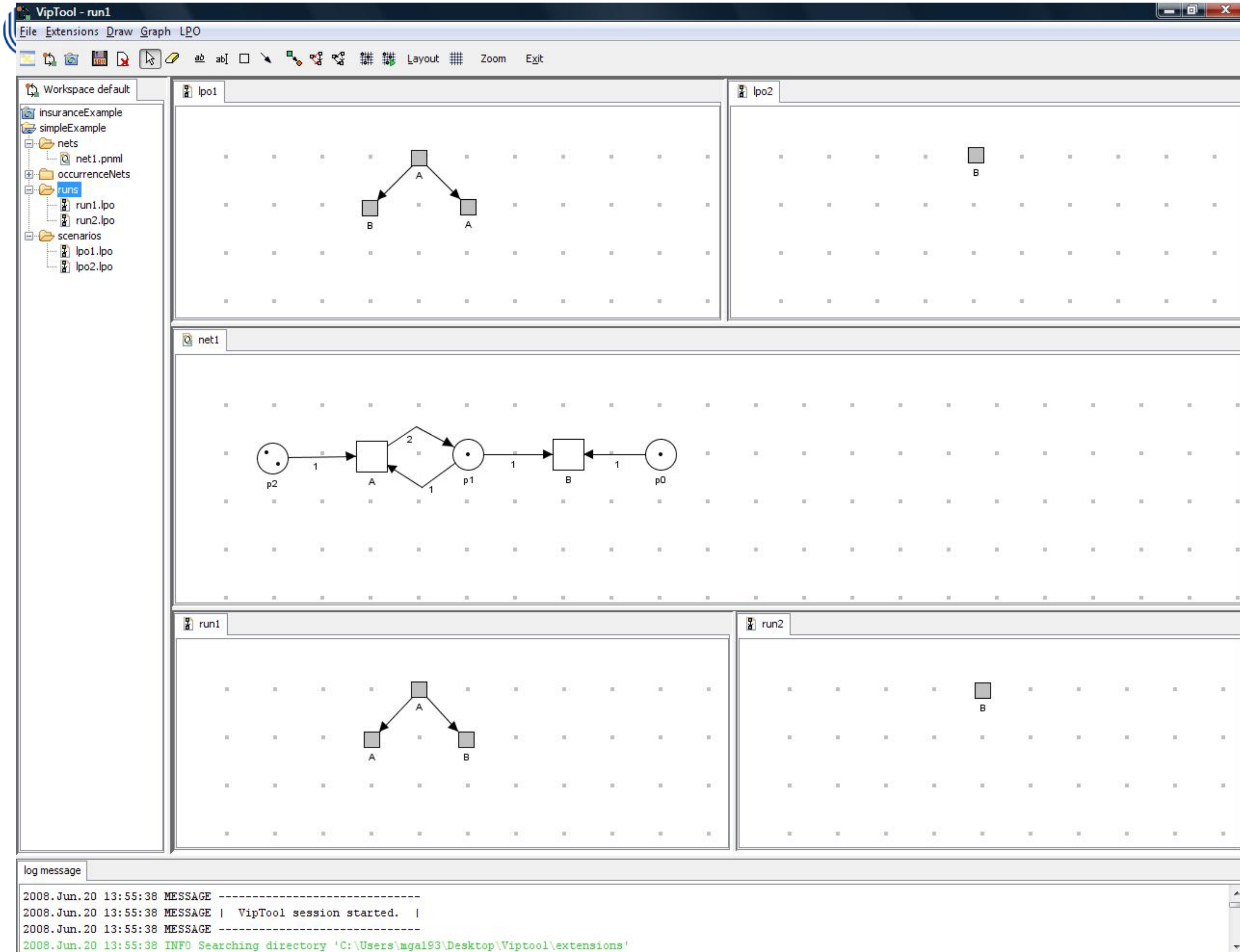
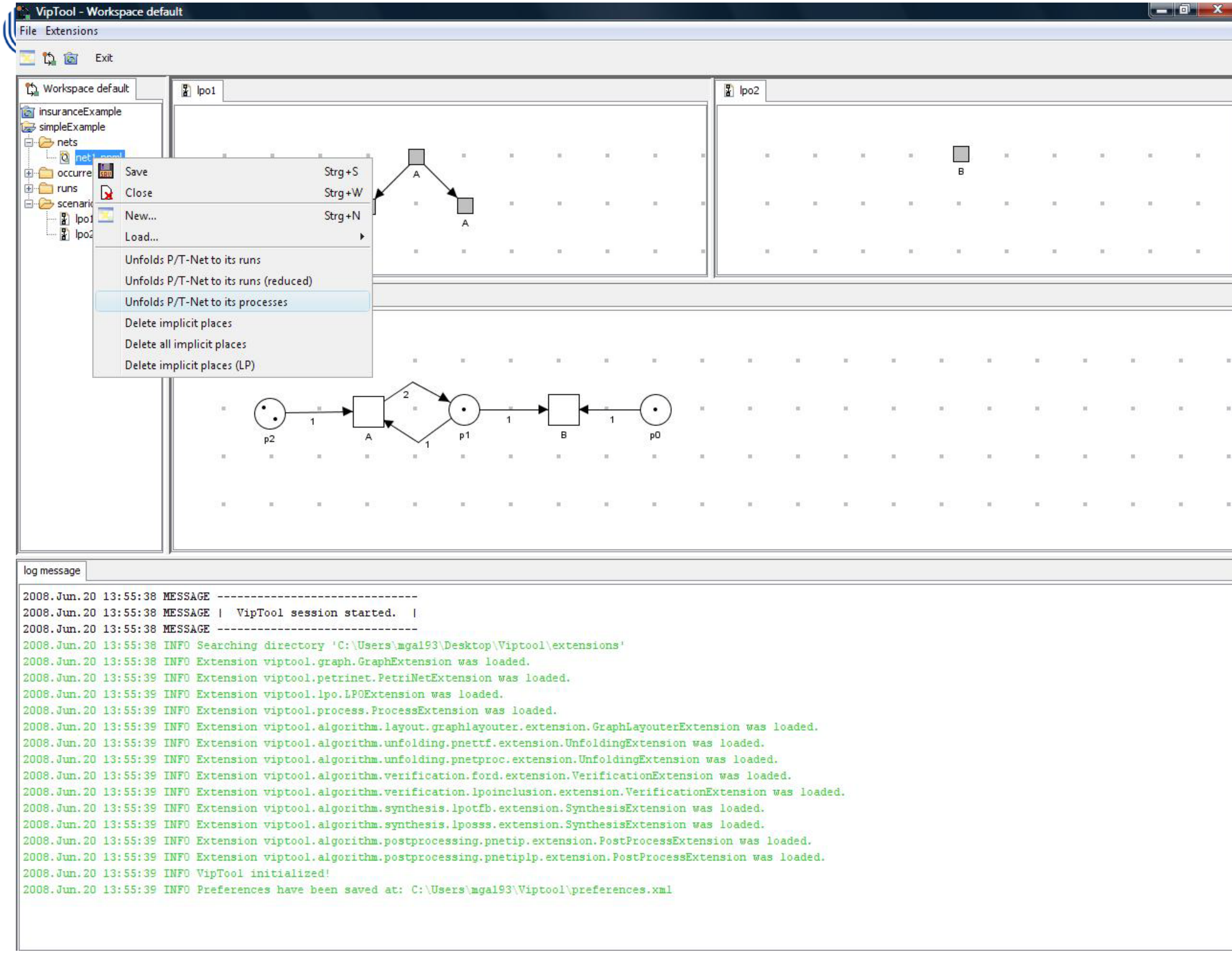

VipTool - run1
File Extensions Draw Graph LPO
Layout
Zoom
Exit
Workspace default
insuranceExample
simpleExample
nets
net1.pnml
occurrenceNets
runs
run1.lpo
run2.lpo
scenarios
lpo1.lpo
lpo2.lpo
lpo1
lpo2
net1
run1
run2
p2
p1
p0
A
B
log message
2008.Jun.20 13:55:38 MESSAGE -----------------------------
2008.Jun.20 13:55:38 MESSAGE | VipTool session started. |
2008.Jun.20 13:55:38 MESSAGE -----------------------------
2008.Jun.20 13:55:38 INFO Searching directory 'C:\Users\mga193\Desktop\Viptool\extensions'


VipTool - Workspace default
File Extensions
Exit
Workspace default
insuranceExample
simpleExample
nets
occurre
runs
scenario
lpo1
lpo2
Save Strg+S
Close Strg+W
New... Strg+N
Load...
Unfolds P/T-Net to its runs
Unfolds P/T-Net to its runs (reduced)
Unfolds P/T-Net to its processes
Delete implicit places
Delete all implicit places
Delete implicit places (LP)
lpo1
lpo2
A
A
B
p2
A
p1
B
p0
log message
2008.Jun.20 13:55:38 MESSAGE -----------------------------
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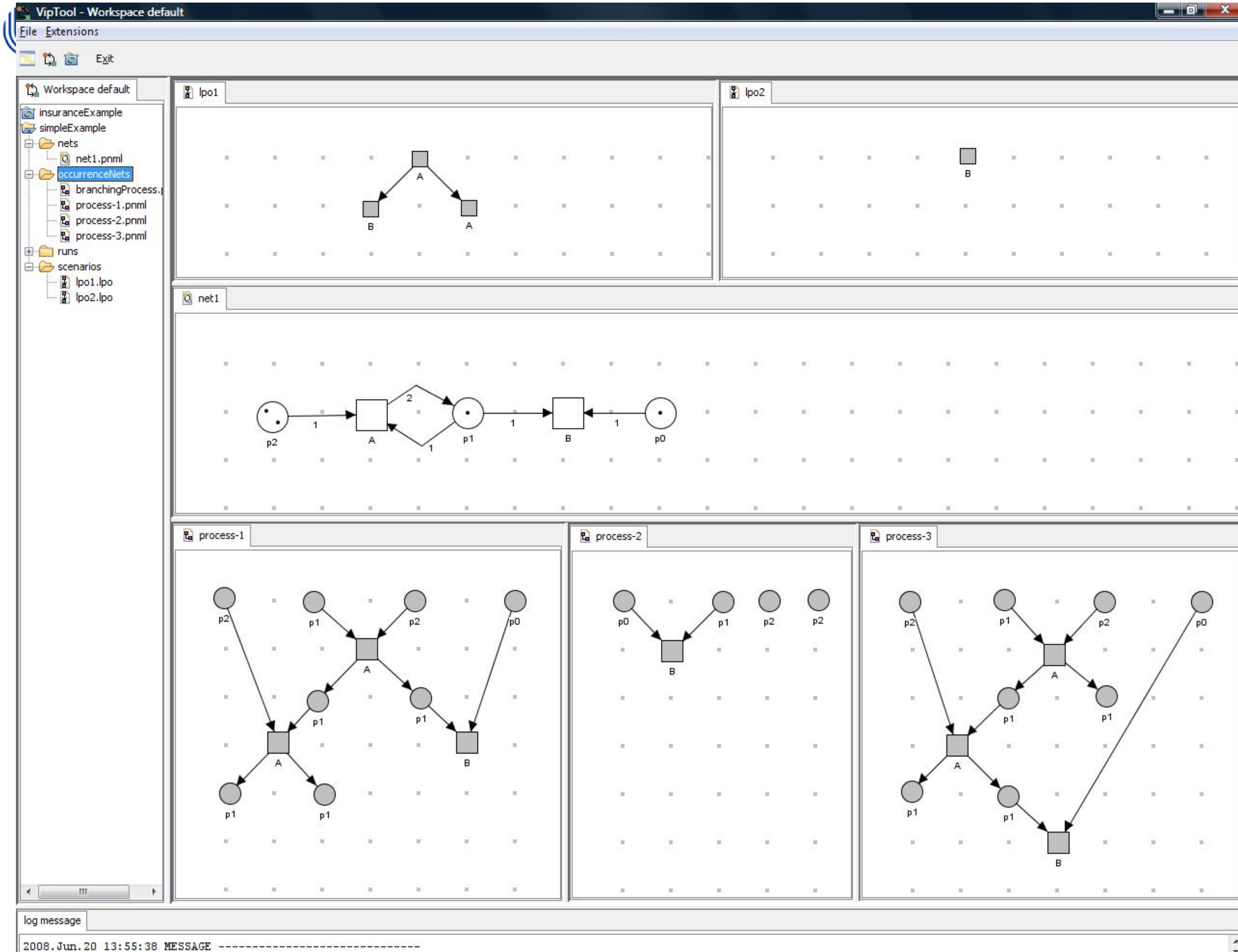
2008.Jun.20 13:55:39 INFO Extension viptool.lpo.LPOExtension was loaded.
2008.Jun.20 13:55:39 INFO Extension viptool.process.ProcessExtension was loaded.
2008.Jun.20 13:55:39 INFO Extension viptool.algorithm.layout.graphlayouter.extension.GraphLayouterExtension was loaded.
2008.Jun.20 13:55:39 INFO Extension viptool.algorithm.unfolding.pnettf.extension.UnfoldingExtension was loaded.
2008.Jun.20 13:55:39 INFO Extension viptool.algorithm.unfolding.pnetproc.extension.UnfoldingExtension was loaded.
2008.Jun.20 13:55:39 INFO Extension viptool.algorithm.verification.ford.extension.VerificationExtension was loaded.
2008.Jun.20 13:55:39 INFO Extension viptool.algorithm.verification.lpoinclusion.extension.VerificationExtension was loaded.
2008.Jun.20 13:55:39 INFO Extension viptool.algorithm.synthesis.lpotfb.extension.SynthesisExtension was loaded.
2008.Jun.20 13:55:39 INFO Extension viptool.algorithm.synthesis.lposss.extension.SynthesisExtension was loaded.
2008.Jun.20 13:55:39 INFO Extension viptool.algorithm.postprocessing.pnetip.extension.PostProcessExtension was loaded.
2008.Jun.20 13:55:39 INFO Extension viptool.algorithm.postprocessing.pnetiplp.extension.PostProcessExtension was loaded.
2008.Jun.20 13:55:39 INFO VipTool initialized!
2008.Jun.20 13:55:39 INFO Preferences have been saved at: C:\Users\mga193\Viptool\preferences.xml


VipTool - Workspace default
File Extensions
Exit
Workspace default
insuranceExample
simpleExample
nets
net1.pnml
occurrenceNets
branchingProcess.
process-1.pnml
process-2.pnml
process-3.pnml
runs
scenarios
lpo1.lpo
lpo2.lpo
lpo1
lpo2
net1
process-1
process-2
process-3
log message
2008.Jun.20 13:55:38 MESSAGE -----------------------------

Partial Orders Fit For Work

Jörg Desel FernUniversität in Hagen