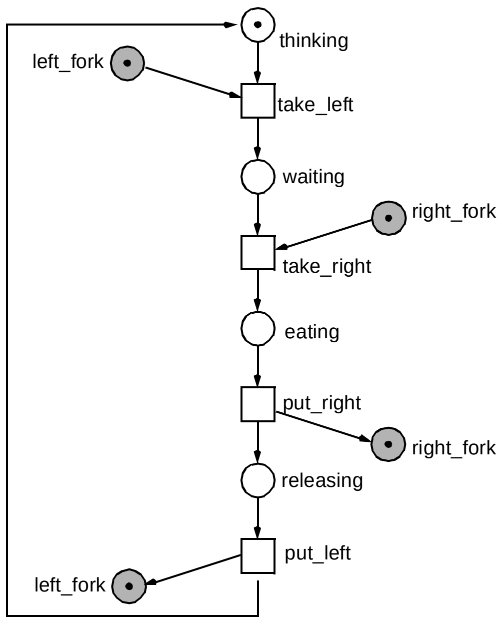
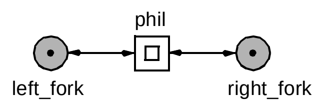
SYSTEM DEADLOCKS - DINING PHILOSOPHERS

DINING PHILOSOPHERS, ONE PHILOSOPHER PN COMPONENT

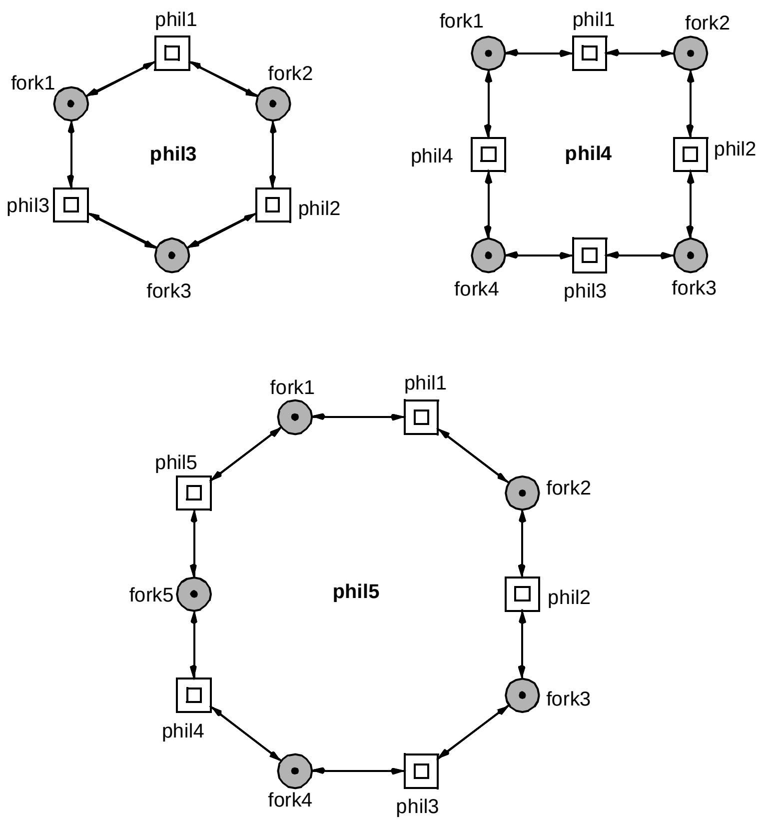




ORD	HOM	NBM	PUR	CSV	SCF	CON	SC	Ft0	tF0	Fp0	pF0	MG	SM	FC	EFC	ES
Y	Y	Y	Y	N	Y	Y	Y	N	N	N	N	Y	N	Y	Y	Y

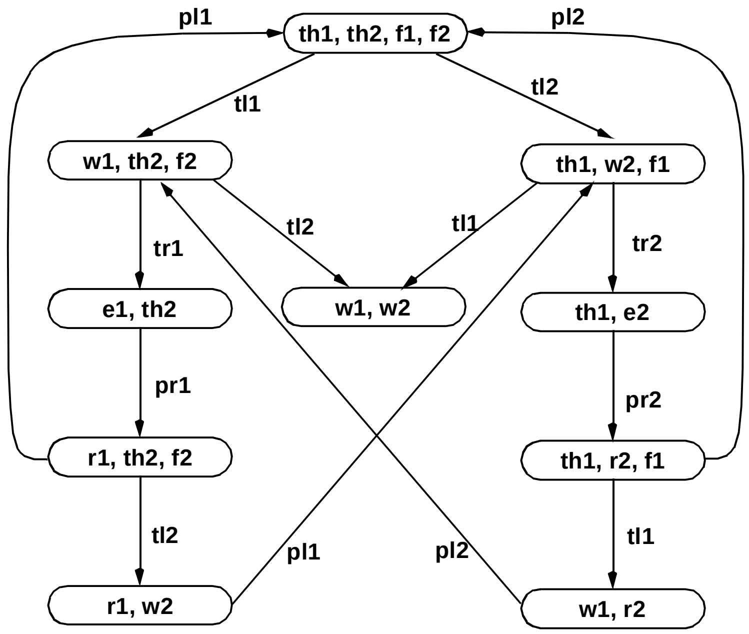
DTP	SMC	SMD	SMA	CPI	CTI	B	SB	REV	DSt	BSt	DTr	DCF	L	LV	L&S
Y	Y	Y	Y	Y	Y	Y	Y	Y	N	?	N	Y	Y	Y	Y

DINING PHILOSOPHERS, SYSTEM OF N PHILOSOPHERS

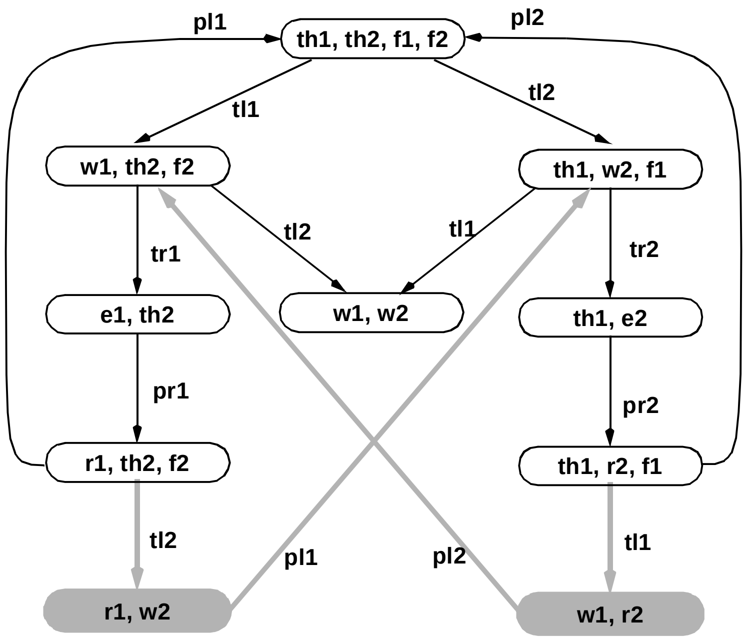


ORD	HOM	NBM	PUR	CSV	SCF	CON	SC	Ft0	tF0	Fp0	pF0	MG	SM	FC	EFC	ES
Y	Y	Y	Y	N	N	Y	Y	N	N	N	N	N	N	N	N	Y
DTP	SMC	SMD	SMA	CPI	CTI	B	SB	REV	DSt	BSt	DTr	DCF	L	LV	L&S	
N	Y	Y	N	Y	Y	Y	Y	N	Y	?	N	N	N	N	N	

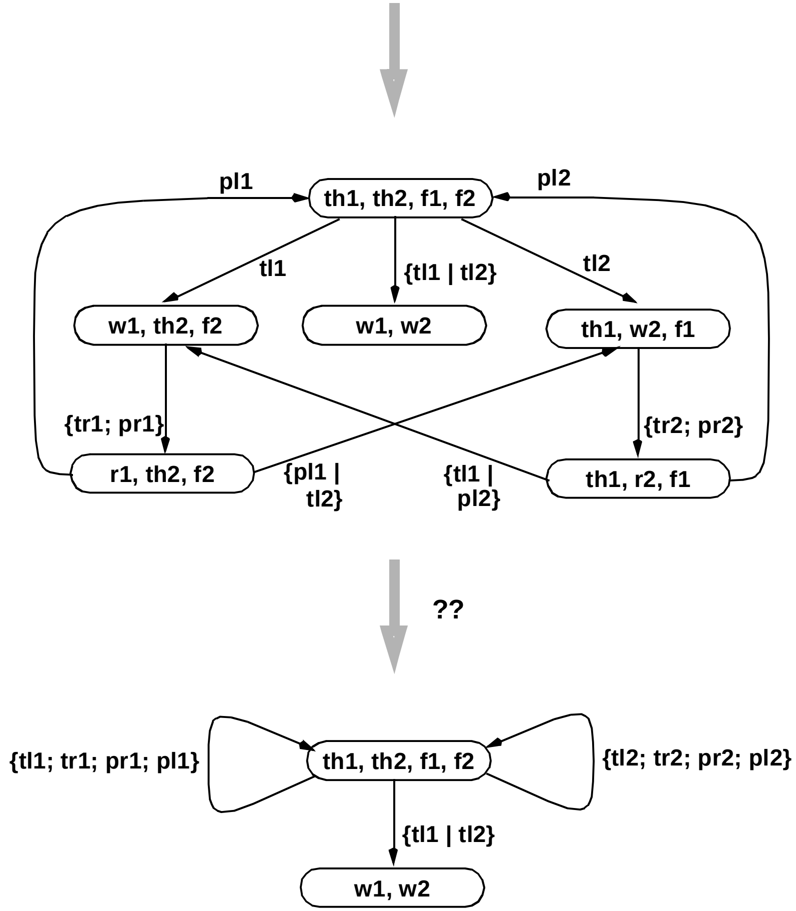
DINING PHILOSOPHERS (2 PHILS), REACHABILITY GRAPH



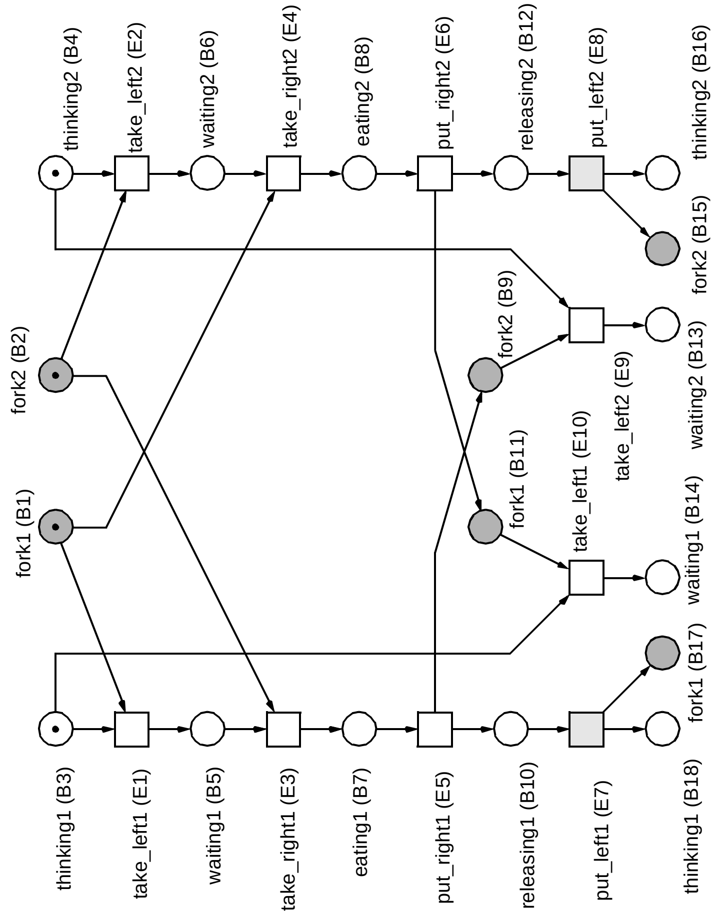
DINING PHILOSOPHERS (2 PHILS), STUBBORN SET REDUCED REACHABILITY GRAPH



DINING PHILOSOPHERS (2 PHILS), CONCURRENT AUTOMATON



DINING PHILOSOPHERS (2 PHILS), FINITE PREFIX OF BRANCHING PROCESSES



DINING PHILOSOPHERS, ANALYSIS EFFORTS WITH INA/PROD

# phils	P / T	INA		PEP	
		R_{stub}	R	B / E	time
1	6 / 4	4	4	9 / 4	
2	10 / 8	8	10	18 / 10	
3	15 / 12	20	35	45 / 27	
4	20 / 16	38	118	84 / 52	
5	25 / 20	62	392	135 / 85	
6	30 / 24	92	1.297	198 / 126	
7	35 / 28	128	4.286	273 / 175	
8	40 / 32	170	14.158	360 / 232	
9	45 / 36	218	46.763	459 / 297	
10	50 / 40	272	154.450	570 / 370	
11	55 / 44	332	510.116	693 / 451	(0 : 5)
12	60 / 48	398		828 / 540	(0 : 23)
13	65 / 52	470	(5.56 e+6)	975 / 637	(1 : 29)
14	70 / 56	548		1.134 / 742	(6 : 28)
15	75 / 60	632	(60.7 e+6)	1.305 / 855	(27 : 42)

DINING PHILOSOPHERS, ANALYSIS EFFORTS WITH SMV (BDD)

#	states	without reordering		computation of reordering		with reordering	
		time	BDD nodes	time	BDD nodes	time	BDD nodes
2	10	0.1”	3120	0.06”	1405	0.1”	3082
3	35	0.17”	7577	0.11”	3895	0.17”	7474
5	392	0.68”	10258	0.87”	5186	0.28”	10037
7	4247	3.09”	12635	5.36”	8800	2.82”	12674
9	46763	16.95”	60310	27.99”	12836	6.16”	16533
11	510116	88.17”	200803	5.99’	49459	25.75”	67469
13	5.56e+6	35.99’	720848	28.10’	165055	1.69’	222471
15	60.7e+6	1.76 h	1369156	41.12’	125471	1.93’	160109

Machine: Hypersparc, 32 MB (britten)
Times: user time + system time
Model checking of the formula AG(_fork1 | _fork2 | ... | forkn)
Comp. of variable reordering perfomed without model checking
smv options: -f -r inc

PHIL1000, BDD-BASED BY JSP

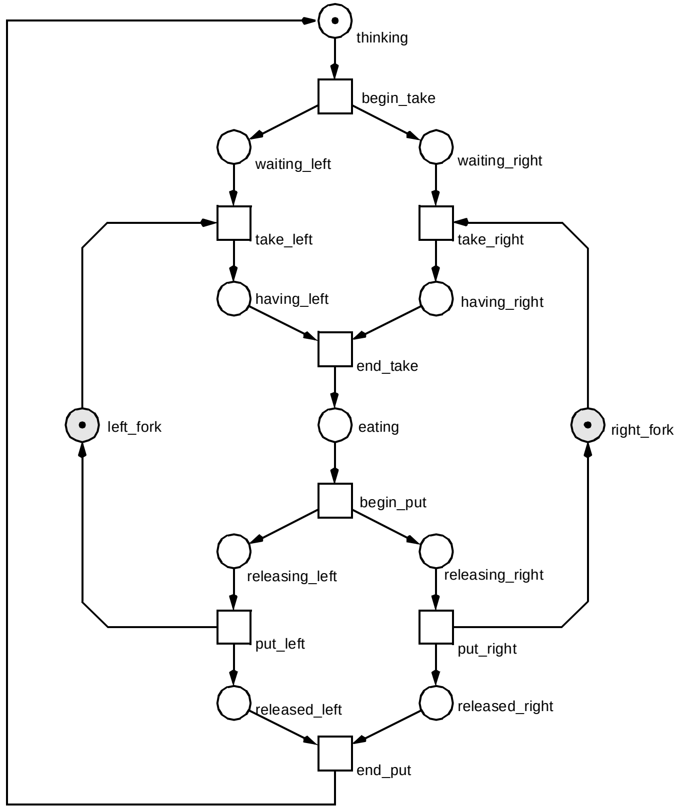
Number of states:

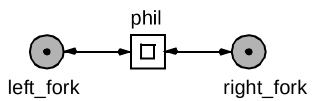
113751760865620516280672035436276768405854187694780001109285823216991 8\\
159959588122031332641120690971790713407413960379370132051412946235771 0\\
244289522738424241885324723952294300718880861927052755597203329394869 1\\
334498271287409035878953318171137286359195790723689557093738307422542 1\\
493299735055934871120872608511650262781852464476299128123872281683542 6\\
439043702222222716712699874004961590120093014497021663026892511863169 6\\
792192797756430854076755677722422066045029462353435568315492194903488 7\\
413893510872611522753508464671945735340847108696533249480549775338294 2\\
171781101168772051021154169003921176627995642292903237688541475038527 5\\
51248819240105363652551190474777411874

ca. 1.1 * 10^667

- ❑ Number of places/marked places/transitions:
  7000/2000/5000
- ❑ Time to compute P-Invariants:
  45885.66 sec
- ❑ Number of P-Invariants:
  3000
- ❑ Time to compute compact coding:
  385.59 sec
- ❑ Number of Clusters:
  3000
- ❑ Number of Variables:
  4000
- ❑ Time: 3285.73 sec, ca. 54.75 min

DINING PHILOSOPHERS, VERSION2
ONE PHILOSOPHER PN COMPONENT






```
ORD HOM NBM PUR CSV SCF CON SC  Ft0 tF0 Fp0 pF0 MG  SM  FC  EFC ES
 Y   Y   Y   Y   N   Y   Y   Y   N   N   N   N   Y   N   Y   Y   Y
DTP SMC SMD SMA CPI CTI  B  SB  REV DSt BSt DTr DCF  L   LV L&S
 Y   Y   Y   Y   Y   Y   Y   Y   Y   N   ?   N   Y   Y   Y   Y
```


DINING PHILOSOPHERS, VERSION2
ANALYSIS EFFORTS WITH INA/PEP

# phils	P / T	INA		PEP	
		R_{stub}	R	B / E	time
1	12 / 8	8	10		
2	22 / 6	18	57		
3	33 / 24	43	446		
4	44 / 32	100	3429		
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

FOUR NECESSARY & SUFFICIENT DEADLOCK CONDITIONS [COFFMAN ET AL]

- mutually exclusive resources
  - -> *shared, serially reusable*
  - -> *unsufficient supply, therefore competition*
- incremental acquisition
  - -> *dynamic resource allocation (in opposite to static one)*
  - -> *processes hold resources while waiting to acquire additonal ones*
- no pre-emption
  - -> *resources cannot be pre-empted (withdrawn forcibly)*
  - -> *resources are only released voluntarily*
- waiting cycle
  - -> *cycle of processes such that each process holds a resource which its neighbour is waiting for*
  - -> *may contain*
    -> all (total deadlock) or
    -> only some of the processes (partial deadlock)
- **ANY DEADLOCK AVOIDANCE POLICY HAS TO ERASE AT LEAST ONE OF THESE CONDITIONS**

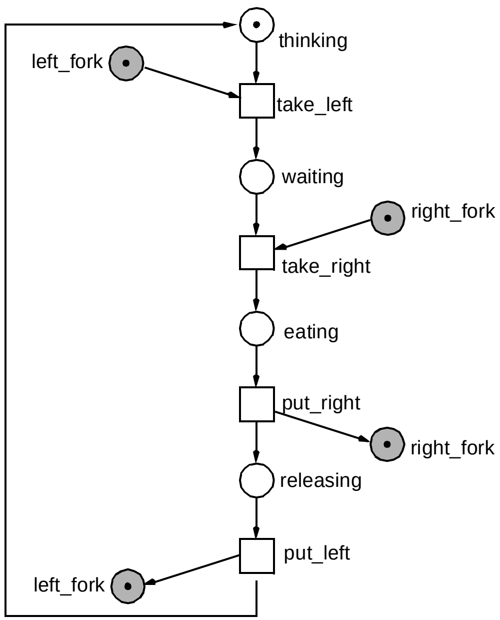
DINING PHILOSOPHERS, DEADLOCK AVOIDANCE STRATEGIES

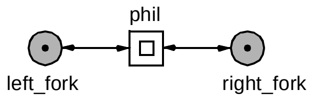
- limit number of phils trying to eat, so there will be enough resources for at least one
  - -> *limit number of chairs*
  - -> *token ring protocol (only one phil can eat at any time)*
  - -> *sequential eating (special token ring)*
  - **=>> *sufficient supply, no competition***
- static allocation (all or nothing)
  - **=>> no incremental acquisition**

  BUT: atomic operation to aquire multiple resources
- wait only finite time
  - **=>> pre-emption, voluntarily**
- asymmetric behaviour
  - -> *only one behaves asymmetrically*
  - -> *even/odd-numbered phils behave differently*
  - -> *hierachical resource allocation*
  - **=>> no waiting cycle**

  BUT: contradiction to original task (identical pattern for all)

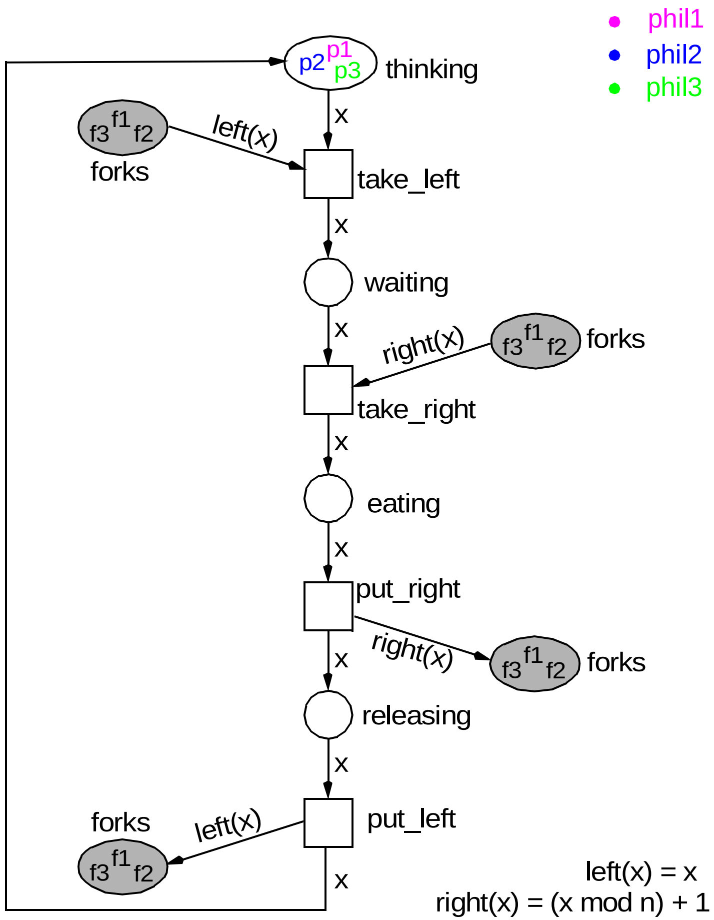
DINING PHILOSOPHERS, ONE PHILOSOPHER PN COMPONENT





ORD	HOM	NBM	PUR	CSV	SCF	CON	SC	Ft0	tF0	Fp0	pF0	MG	SM	FC	EFC	ES
Y	Y	Y	Y	N	Y	Y	Y	N	N	N	N	Y	N	Y	Y	Y
DTP	SMC	SMD	SMA	CPI	CTI	B	SB	REV	DSt	BSt	DTr	DCF	L	LV	L&S	
Y	Y	Y	Y	Y	Y	Y	Y	Y	N	?	N	Y	Y	Y	Y	

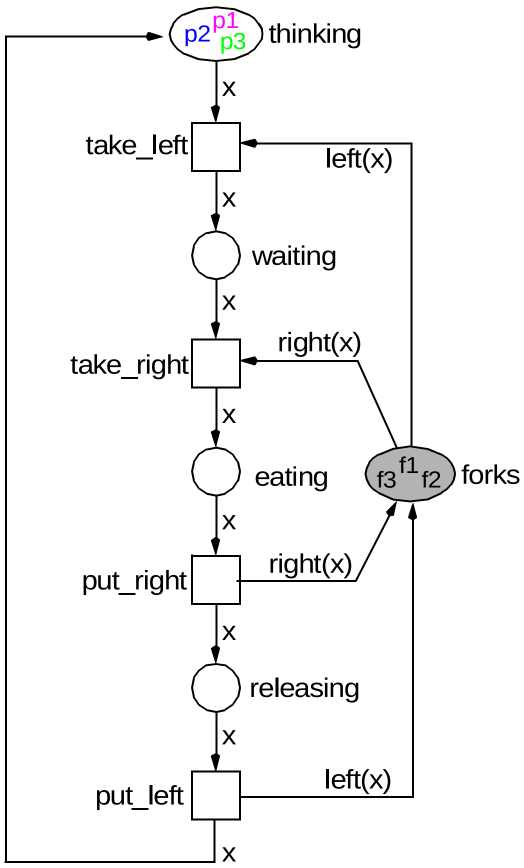
DINING PHILOSOPHERS, AS COLOURED PN (1)



left(x) = x
right(x) = (x mod n) + 1

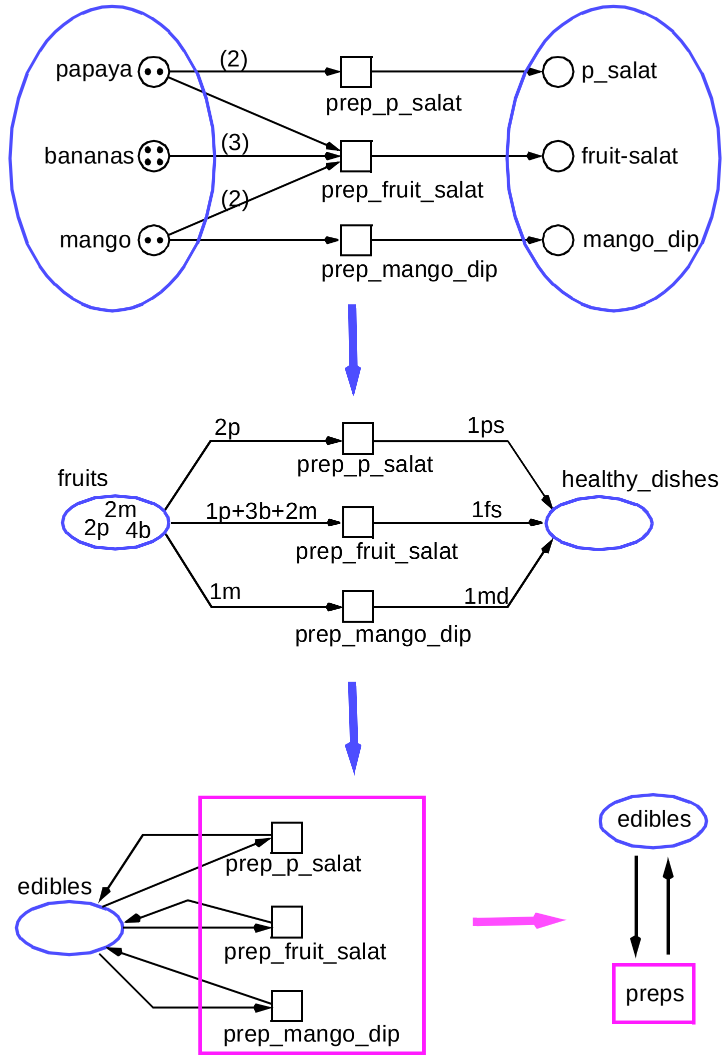
colour(thinking) = ... = colour(releasing) = {p1, p2, p3}
colour(take_left) = ... = colour(put_left) = {p1, p2, p3}
colour(forks) = {f1, f2, f3}

DINING PHILOSOPHERS, AS COLOURED PN (2)



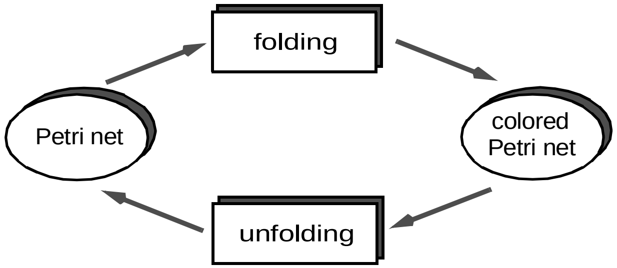
-> net scheme for any number of philosophers

COLOURED PETRI NETS, EXAMPLE2



COLOURED PETRI NETS, BASICS

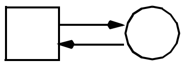
- ❑ information-preserving transformation processes



- ❑ folding needs user interaction

- ❑ trivial transformation: only one color (black color)
  - -> *no structure compression*

- ❑ any Petri net may be transformed into



  - -> all structure information in arc inscriptions

- ❑ readability depends on readability of arc inscription

COLOURED PETRI NETS, ANALYSIS

- ❑ by unfolding
  - -> *reuse of all P/T net analysis techniques*
  - -> *symmetrically reduced rg*

- ❑ without unfolding
  - -> *reachability graph (CPN - occurrence graph)*
  - -> *invariants (tools ?)*
  - -> *CTL model checking (tools ?)*

- ❑ dedicated notion of liveness: collectively live transitions
  - -> *all transition colours of a given coloured transition guarantee together the liveness*
  - -> *very useful for control flow models*