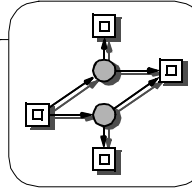


Brandenburg Technical
University at Cottbus,
Computer Science Institute

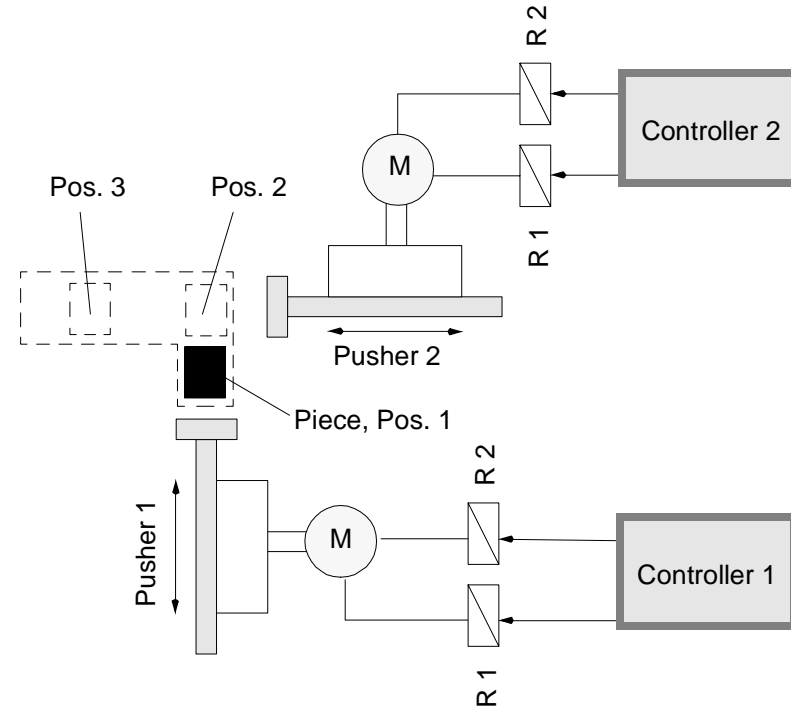
CASE STUDY CONCURRENT PUSHERS

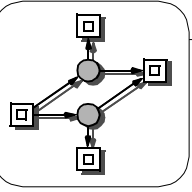
MONIKA HEINER

monika.heiner@informatik.tu-cottbus.de
<http://www.informatik.tu-cottbus.de>



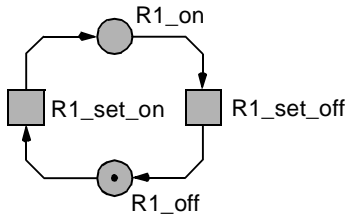
EXAMPLE - CONCURRENT PUSHERS:



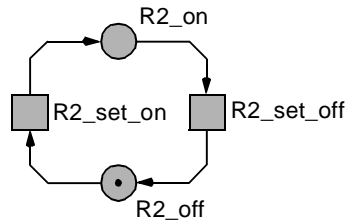


ENVIRONMENT MODEL, WITHOUT ERROR STATES:

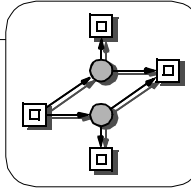
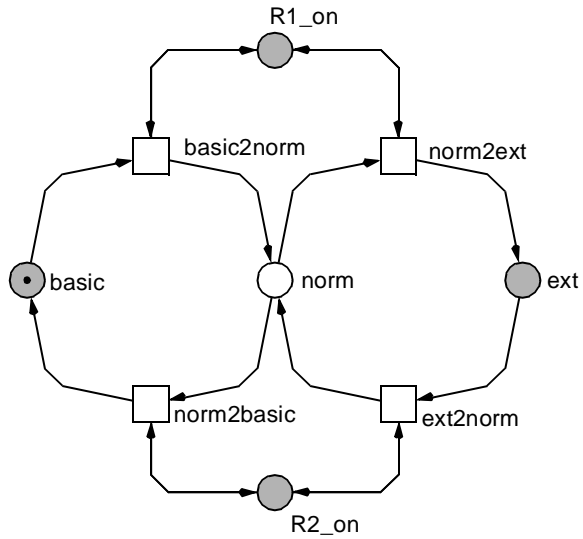
RELAY R1



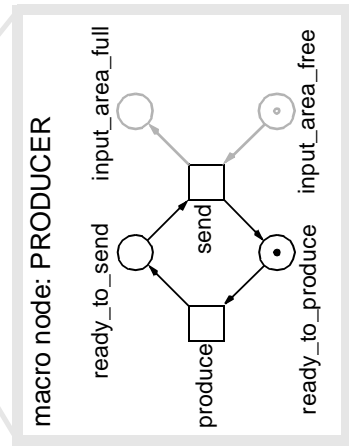
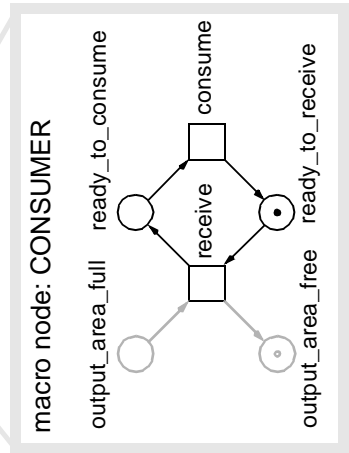
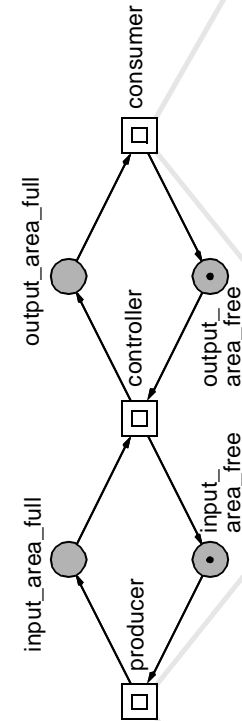
RELAY R2

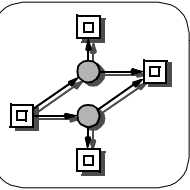


PUSHER without error states

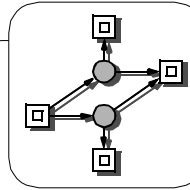
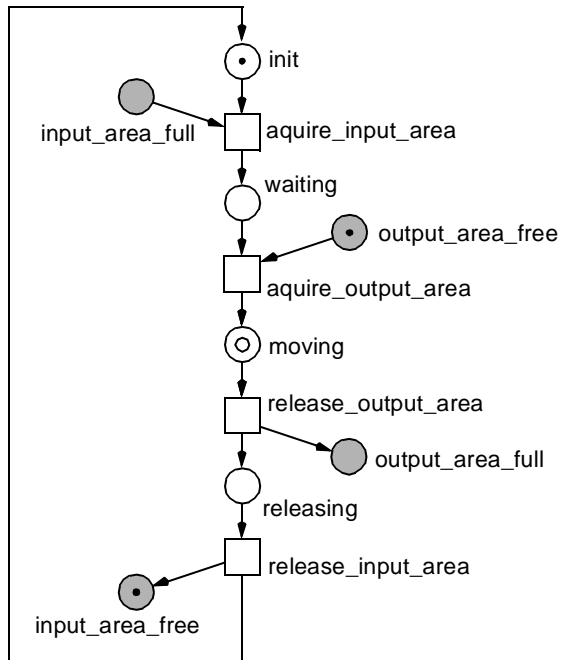


PUSHER, PRODUCER CONSUMER RELATION:

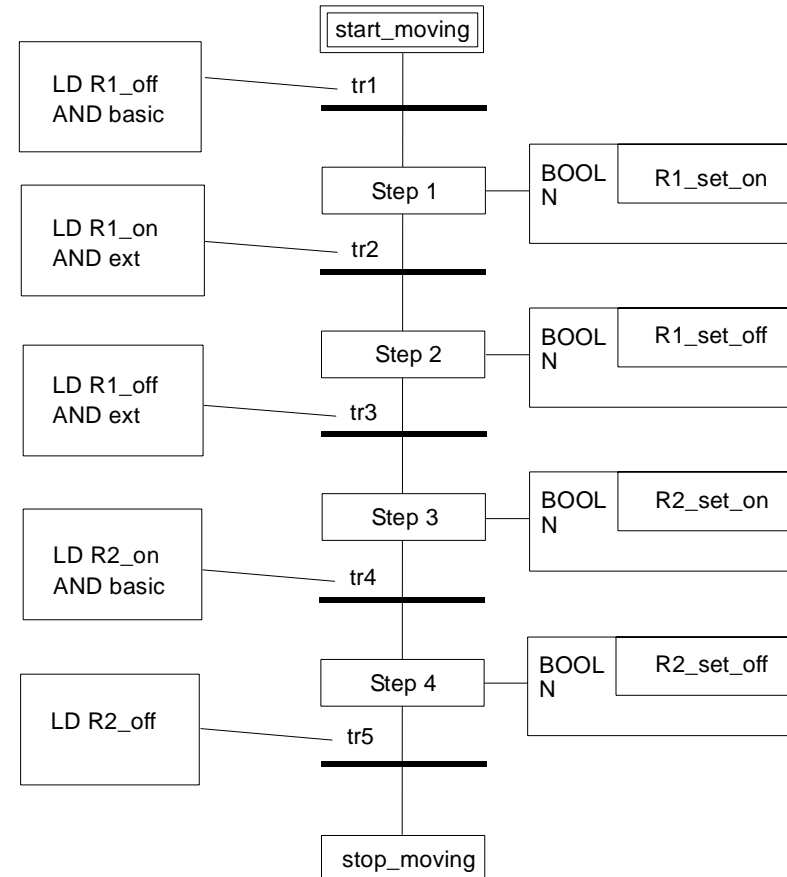




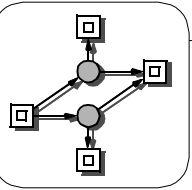
CONTROLLER AS PLACE/TRANSITION NET, COOPERATION MODEL:



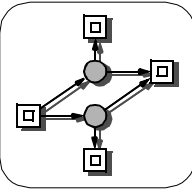
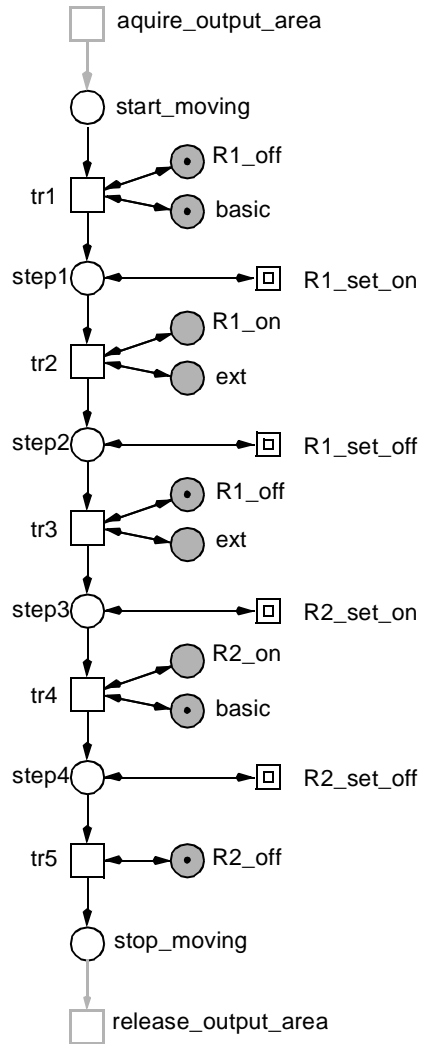
CONTROLLER (KERNEL) AS PLC PROGRAM:



[Rausch 96]

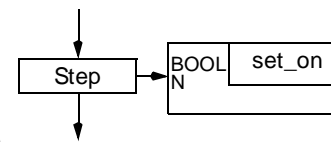


CONTROLLER (KERNEL) AS PLACE/TRANSITION NET, CONTROL MODEL

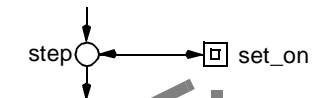


BASIC STEP MODELLING:

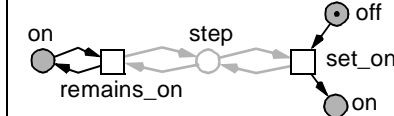
SFC:



PN:

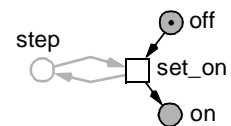


version 1a



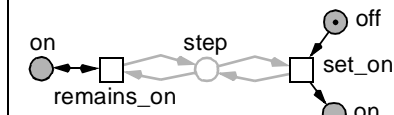
not DCF

version 2



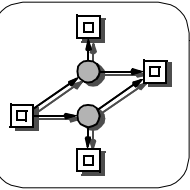
DCF

version 1b



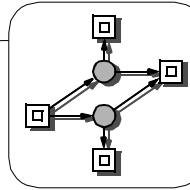
DCF

READ ARC



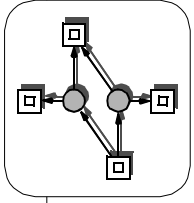
PUSHERS / V1, ANALYSIS EFFORTS INA, PEP, SMV

# pushers	P / T	R	R _{stub}	prefix B / E	SMV BDD nodes
1	24 / 25	88	22	128 / 61	10.027
2	42 / 46	464	42	293 / 139	10.280
3	60 / 67	3.088	79	510 / 242	10.870
4	78 / 88	18.848	133	779 / 370	18.390
5	96 / 109	118.624	204	1.100 / 523	41.340
6	114 / 130	0.7 e+6	292	1.473 / 701	96.023
7	132 / 151	4.6 e+6	397	?	189.650
8	150 / 172	28.9 e+6	519	?	358.520
9	168 / 193	179.8 e+6	658	?	?
10	186 / 214	1.1 e+9	814	?	?



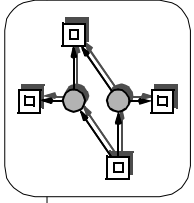
PUSHERS / V2, ANALYSIS EFFORTS INA, PEP, SMV

# pushers	P / T	R	R _{stub}	prefix B / E	SMV BDD nodes
1	24 / 21	88	22	96 / 45	10.029
2	42 / 38	464	42	213 / 99	10.294
3	60 / 55	3.088	79	366 / 170	11.266
4	78 / 72	18.848	133	555 / 258	17.135
5	96 / 89	118.624	204	780 / 363	47.056
6	114 / 106	0.7 e+6	292	1.041 / 485	62.794
7	132 / 123	4.6 e+6	397	1.338 / 624	133.823
8	150 / 140	28.9 e+6	519	1.671 / 780	210.249
9	168 / 157	179.8 e+6	658	2.040 / 953	?
10	186 / 174	1.1 e+9	814	2.445 / 1.143	?



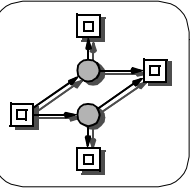
CHAINS OF CONCURRENT PUSHERS / V1, BDD ANALYSIS EFFORTS (SMV)

# pushers	states	without reordering		computation of reordering		with reordering	
		time	BDD nodes	time	BDD nodes	time	BDD nodes
1	88	2.28"	11.105	2.76"	6.320	0.41"	10.027
2	464	32.66"	22.592	18.57"	6.558	14.06"	10.280
3	3.088	2.6'	38.559	1.63'	7.169	56.11"	10.870
4	18.848	8.27'	57.591	5.58'	13.017	3.48'	18.390
5	118.624	23.89'	83.281	16.38	31.596	9.88'	41.340
6	7.3 e+6	1.09 h	163.261	59.22'	71.053	31.4'	96.023
7	4.6 e+6	3.44 h	322.431	3.02 h	135.290	1.36 h	189.650
8	28.9 e+6	13.47 h	572.918	7.27 h	270.239	3.78 h	358.520
9	179.8 e+6				?		
10	1.1 e+9				?		



CHAINS OF CONCURRENT PUSHERS / V2, BDD ANALYSIS EFFORTS (SMV)

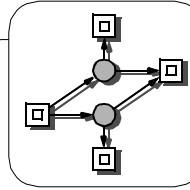
# pushers	states	without reordering		computation of reordering		with reordering	
		time	BDD nodes	time	BDD nodes	time	BDD nodes
1	88	0.74"	10.246	2.36"	5.825	0.36"	10.029
2	464	20.3"	16.436	15.63"	6.737	12.2"	10.294
3	3.088	1.64'	29.214	1.38'	10.787	57.49"	11.266
4	18.848	5.46'	43.694	3.93'	11.849	3.13'	17.135
5	118.624	16.21'	71.118	15.29'	35.209	11.65'	47.056
6	0.7 e+6	49.58'	128.415	41.38	48.782	26.15'	62.794
7	4.6 e+6	2.43 h	249.861	1.91 h	100.899	59.2'	133.823
8	28.9 e+6	10.24 h	431.486	4.63 h	155.688	3.35 h	210.249
9	179.8 e+6						
10	1.1 e+9						



PUSHERS, BDD ANALYSIS EFFORTS (XXX)

# pushers	P / T	R	V1	V2
1	24 / 21	88	0.45 s	0.44 s
2	42 / 38	464	0.66 s	0.75 s
3	60 / 55	3.088	1.96 s	1.69 s
4	78 / 72	18.848	5.59 s	4.38 s
5	96 / 89	118.624	14.71 s	11.43 s
6	114 / 106	0.7 e+6	36.50 s	27.61 s
7	132 / 123	4.6 e+6	74.45 s	56.86 s
8	150 / 140	28.9 e+6	135.77 s	103.39 s
9	168 / 157	179.8 e+6	235.46 s	175.53 s
10	186 / 174	1.1 e+9	387.95 s	278.31 s

time to construct state space



CONCURRENT PUSHERS, TYPICAL SAFETY PROPERTIES:

- At any time, a pusher can be driven in one direction only:

$$AG(\neg(Pi_R1_on \wedge Pi_R2_on)), \forall i$$

- To avoid collisions, it is not allowed to move adjacent pushers at the same time:

$$\left(\sum_{i=1}^2 Pj_Ri_on + \sum_{i=1}^2 Pk_Ri_on \right) \leq 1$$

$$, \forall j, k : j + 1 = k$$

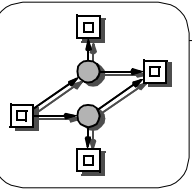
- While moving a pusher, a new work piece must not arrive in its input position:

$$AG(posi_full \rightarrow Pi_basic), \forall i$$

- No pusher motion must be driven too far / near:

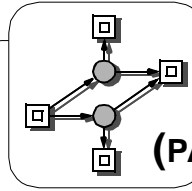
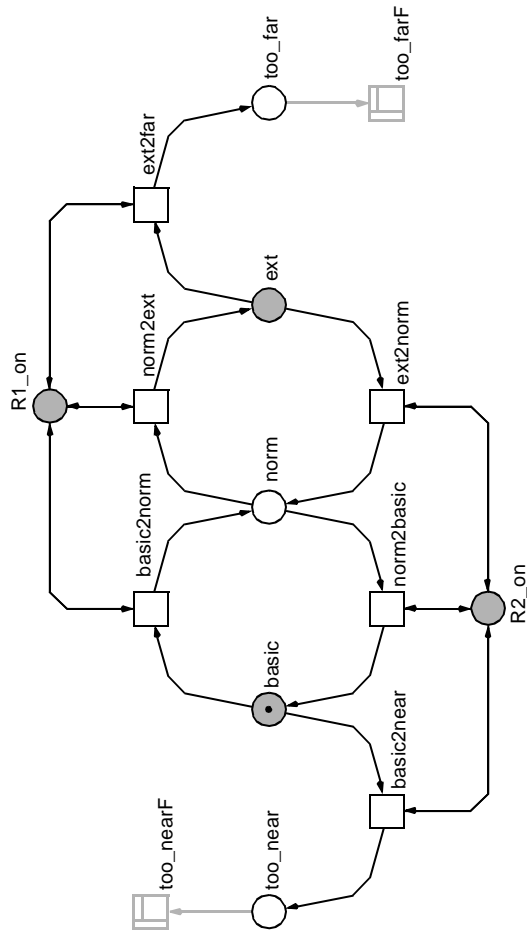
$$AG(\neg Pi_too_near), \forall i$$

$$AG(\neg Pi_too_far), \forall i$$

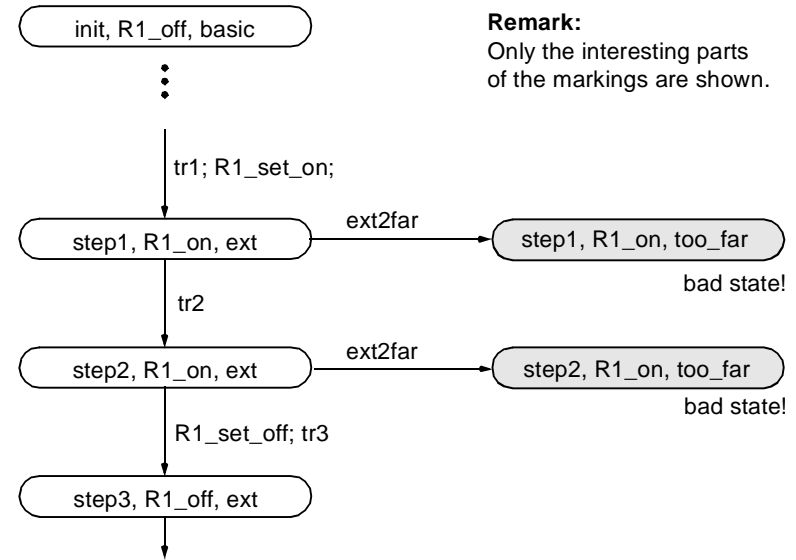


ENVIRONMENT MODEL, WITH EXPLICIT ERROR STATES:

PUSHER
with error states



CONCURRENT PUSHERS, (PART OF THE) REACHABILITY GRAPH:



Remark:
Only the interesting parts
of the markings are shown.

-> (preemptive) interval nets

unreachability of bad states,
 m_0 -dead(ext2far) if:

$$lft(tr2) < eft(ext2far) \wedge$$

$$lft(R1_set_off) < eft(ext2far)$$