Multi-Agent Path Finding

by Marcus Funke and Max Wiedenhöft

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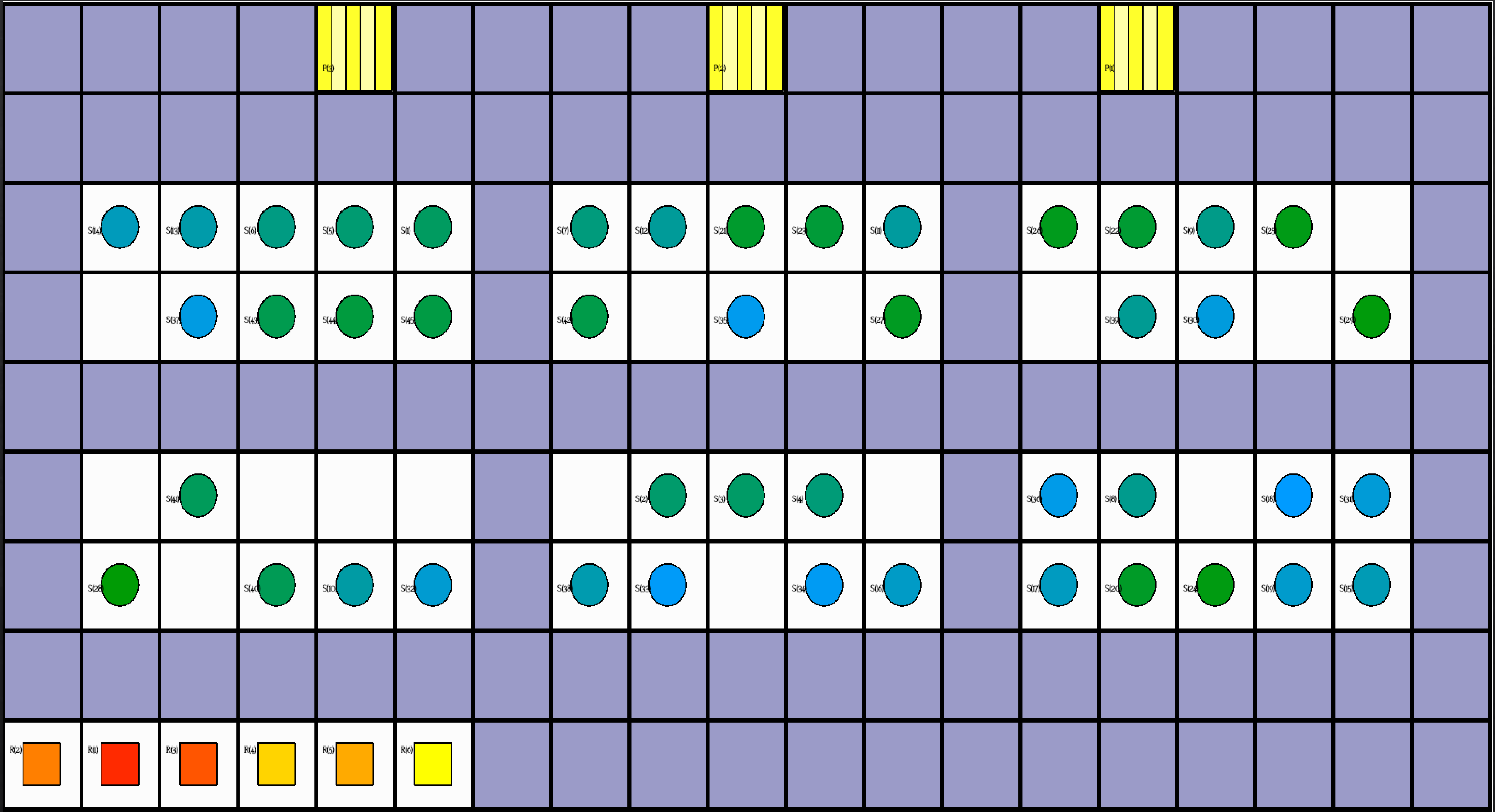
Explanation of asprilo and MAPF

- asprilo
  - Benchmark environment
    - Benchmark Generator
    - Solution Checker
    - Visualizer
    - Referencing Encodings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Explanation of asprilo and MAPF

- asprilo
  - Benchmark environment
  - Various problem Domains(A,B,C,M)

Explanation of asprilo and MAPF

- asprilo
  - Benchmark environment
  - Various problem Domains(A,B,C,M)
- **M**ulti **A**gent **P**ath **F**inding

Details of the Merger

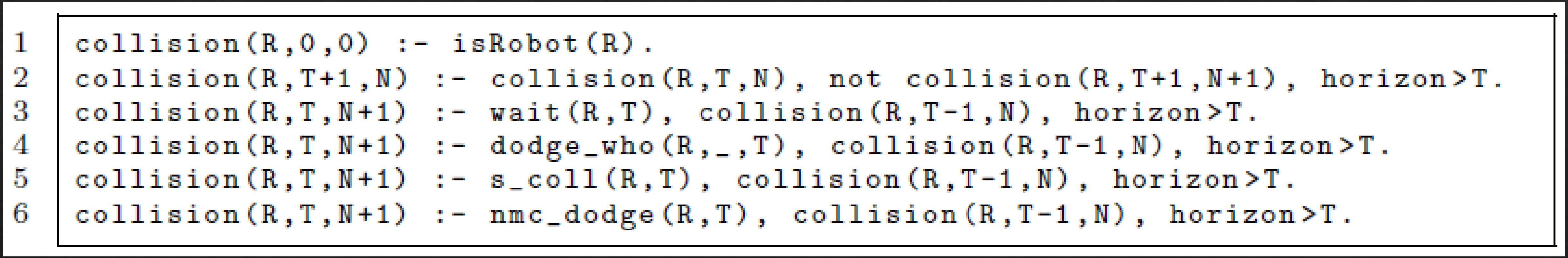
- 2.1 Basics

Basics

- plan_occurs/3 & step_move/4 & step_pickup/4 & step_putdown/4

Basics

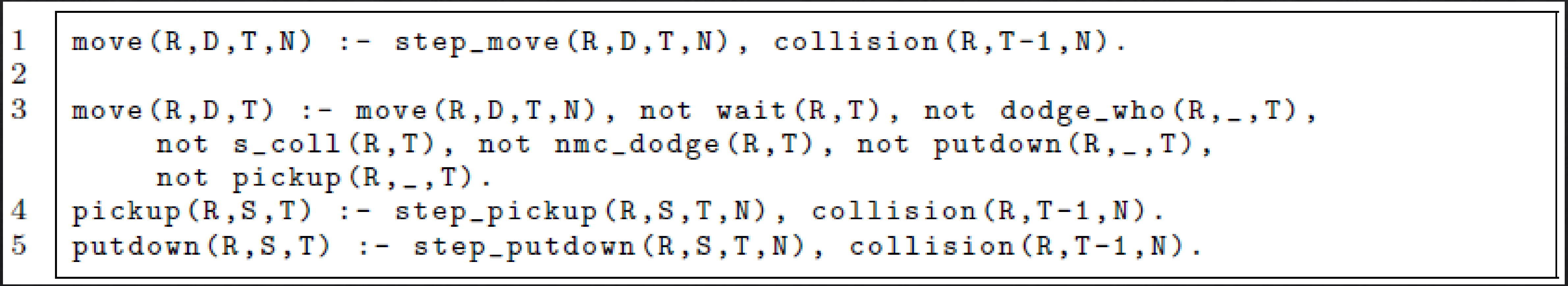
- plan_occurs/3 & step_move/4 & step_pickup/4 & step_putdown/4
- collision/3



```
collision(R,0,0) :- isRobot(R).
collision(R,T+1,N) :- collision(R,T,N), not collision(R,T+1,N+1), horizon>T.
collision(R,T,N+1) :- wait(R,T), collision(R,T-1,N), horizon>T.
collision(R,T,N+1) :- dodge_who(R,_,T), collision(R,T-1,N), horizon>T.
collision(R,T,N+1) :- s_coll(R,T), collision(R,T-1,N), horizon>T.
collision(R,T,N+1) :- nmc_dodge(R,T), collision(R,T-1,N), horizon>T.
```

Basics

- plan_occurs/3 & step_move/4 & step_pickup/4 & step_putdown/4
- collision/3
- move/4
- move/3 & pickup/3 & putdown/3



```
move(R,D,T,N) :- step_move(R,D,T,N), collision(R,T-1,N).

move(R,D,T) :- move(R,D,T,N), not wait(R,T), not dodge_who(R,_,T),
     not s_coll(R,T), not nmc_dodge(R,T), not putdown(R,_,T),
     not pickup(R,_,T).
pickup(R,S,T) :- step_pickup(R,S,T,N), collision(R,T-1,N).
putdown(R,S,T) :- step_putdown(R,S,T,N), collision(R,T-1,N).
```

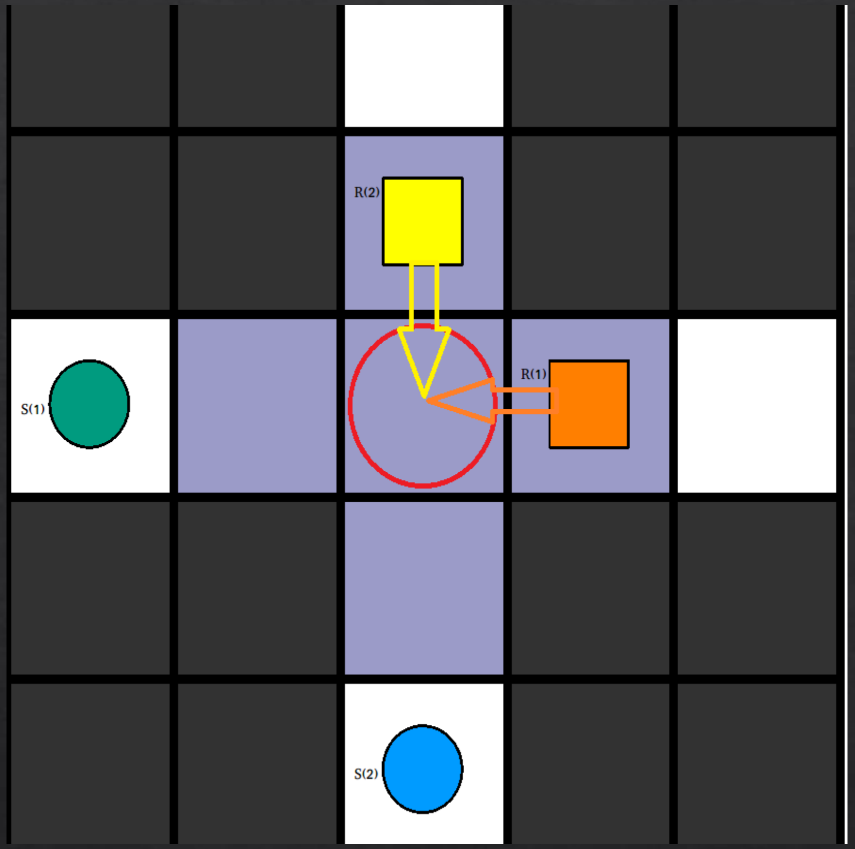
Basics

- plan_occurs/3 & step_move/4 & step_pickup/4 & step_putdown/4
- collision/3
- move/4
- move/3 & pickup/3 & putdown/3
- position/3 & carries/3

Details of the Merger

- 2.1 Basics
- 2.2 Use cases
    - 2.2.1 vertex collision

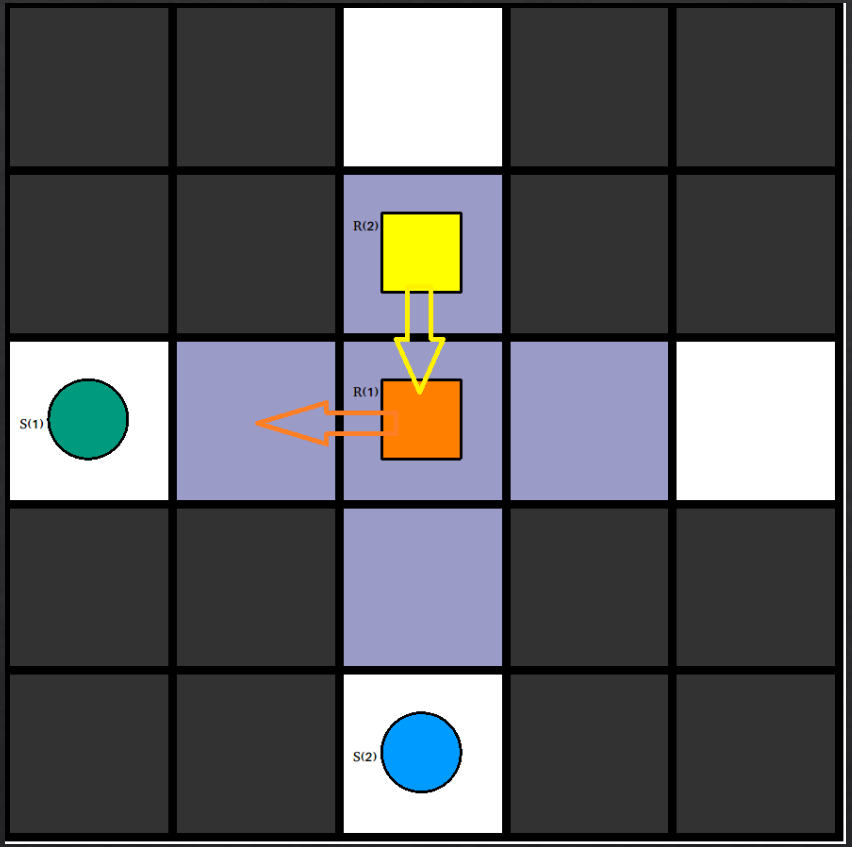
Vertex collision



- wait/2

```
wait(R2,T) :- move(R1,D1,T,N1), move(R2,D2,T,N2), position(R1,C1',T-1),
    N1>N2, nextto(C1',D1,C), position(R2,C2',T-1), nextto(C2',D2,C),
    not dodge_who(R2,_,T), not wait(R1,T).
wait(R2,T) :- move(R1,D1,T,N), move(R2,D2,T,N), position(R1,C1',T-1), R2>R1,
    nextto(C1',D1,C), position(R2,C2',T-1), nextto(C2',D2,C),
    not dodge_who(R2,_,T), not dodge_who(R1,_,T), not no_dodge(R2,T).
```

```
step_move(R,D,T1+1,N+1) :- step_move(R,D,T1,N), wait(R,T),
    collision(R,T-1,N),(T1+1)>T, horizon>T1.
step_pickup(R,S,T1+1,N+1) :- step_pickup(R,S,T1,N), wait(R,T),
    collision(R,T-1,N),(T1+1)>T, horizon>T1.
step_putdown(R,S,T1+1,N+1) :- step_putdown(R,S,T1,N), wait(R,T),
    collision(R,T-1,N),(T1+1)>T, horizon>T1.
```



Vertex collision

- wait/2

```
wait(R2,T) :- move(R1,D1,T,N1), move(R2,D2,T,N2), position(R1,C1',T-1),
    N1>N2, nextto(C1',D1,C), position(R2,C2',T-1), nextto(C2',D2,C),
    not dodge_who(R2,_,T), not wait(R1,T).
wait(R2,T) :- move(R1,D1,T,N), move(R2,D2,T,N), position(R1,C1',T-1), R2>R1,
    nextto(C1',D1,C), position(R2,C2',T-1), nextto(C2',D2,C),
    not dodge_who(R2,_,T), not dodge_who(R1,_,T), not no_dodge(R2,T).
```

```
step_move(R,D,T1+1,N+1) :- step_move(R,D,T1,N), wait(R,T),
    collision(R,T-1,N),(T1+1)>T, horizon>T1.
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    collision(R,T-1,N),(T1+1)>T, horizon>T1.
step_putdown(R,S,T1+1,N+1) :- step_putdown(R,S,T1,N), wait(R,T),
    collision(R,T-1,N),(T1+1)>T, horizon>T1.
```
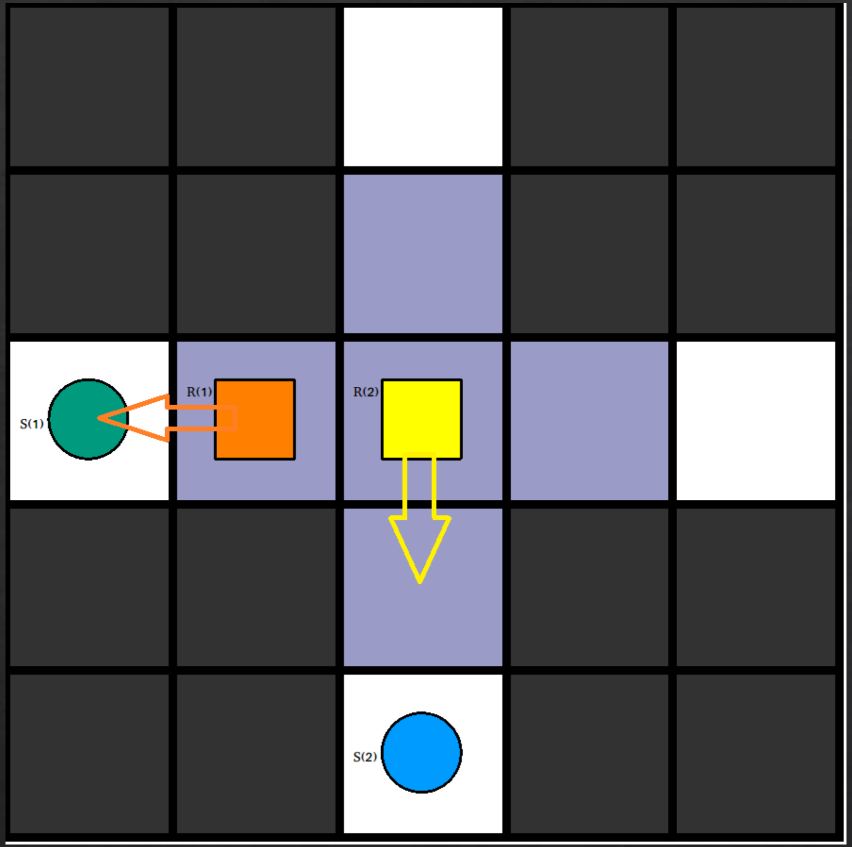



Vertex collision

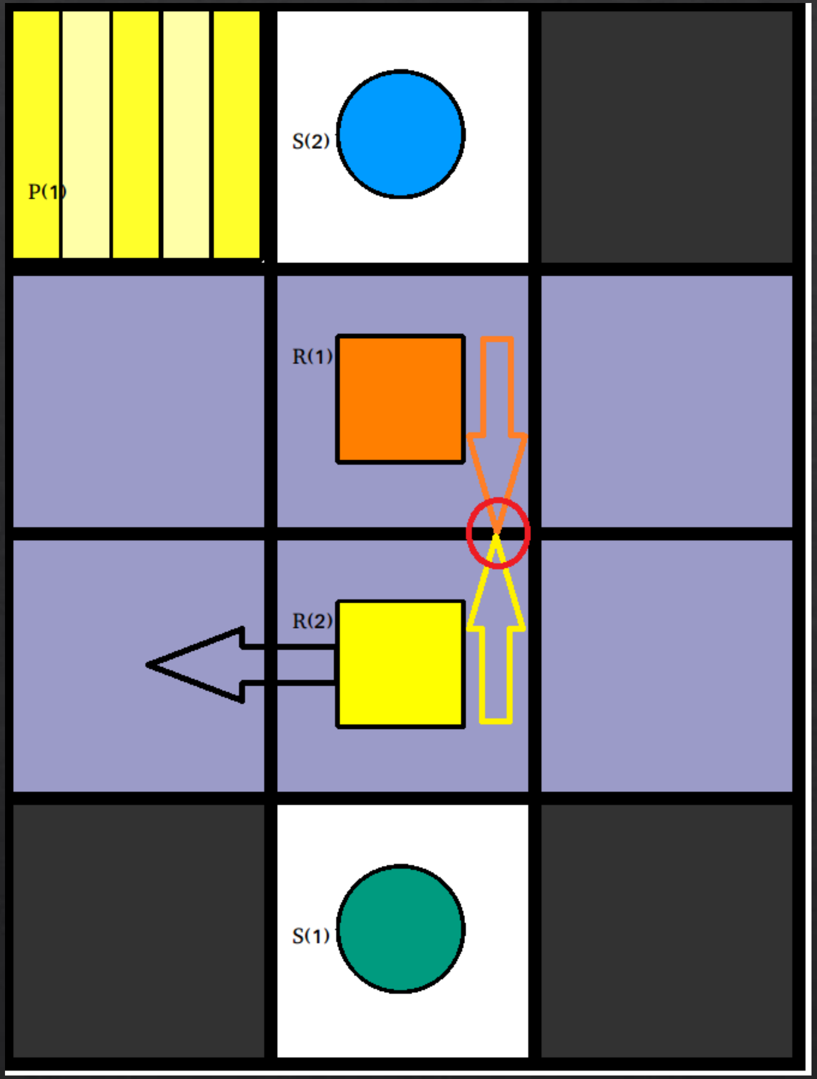
- wait/2

```
wait(R2,T) :- move(R1,D1,T,N1), move(R2,D2,T,N2), position(R1,C1',T-1),
    N1>N2, nextto(C1',D1,C), position(R2,C2',T-1), nextto(C2',D2,C),
    not dodge_who(R2,_,T), not wait(R1,T).
wait(R2,T) :- move(R1,D1,T,N), move(R2,D2,T,N), position(R1,C1',T-1), R2>R1,
    nextto(C1',D1,C), position(R2,C2',T-1), nextto(C2',D2,C),
    not dodge_who(R2,_,T), not dodge_who(R1,_,T), not no_dodge(R2,T).
```

```
step_move(R,D,T1+1,N+1) :- step_move(R,D,T1,N), wait(R,T),
    collision(R,T-1,N),(T1+1)>T, horizon>T1.
step_pickup(R,S,T1+1,N+1) :- step_pickup(R,S,T1,N), wait(R,T),
    collision(R,T-1,N),(T1+1)>T, horizon>T1.
step_putdown(R,S,T1+1,N+1) :- step_putdown(R,S,T1,N), wait(R,T),
    collision(R,T-1,N),(T1+1)>T, horizon>T1.
```

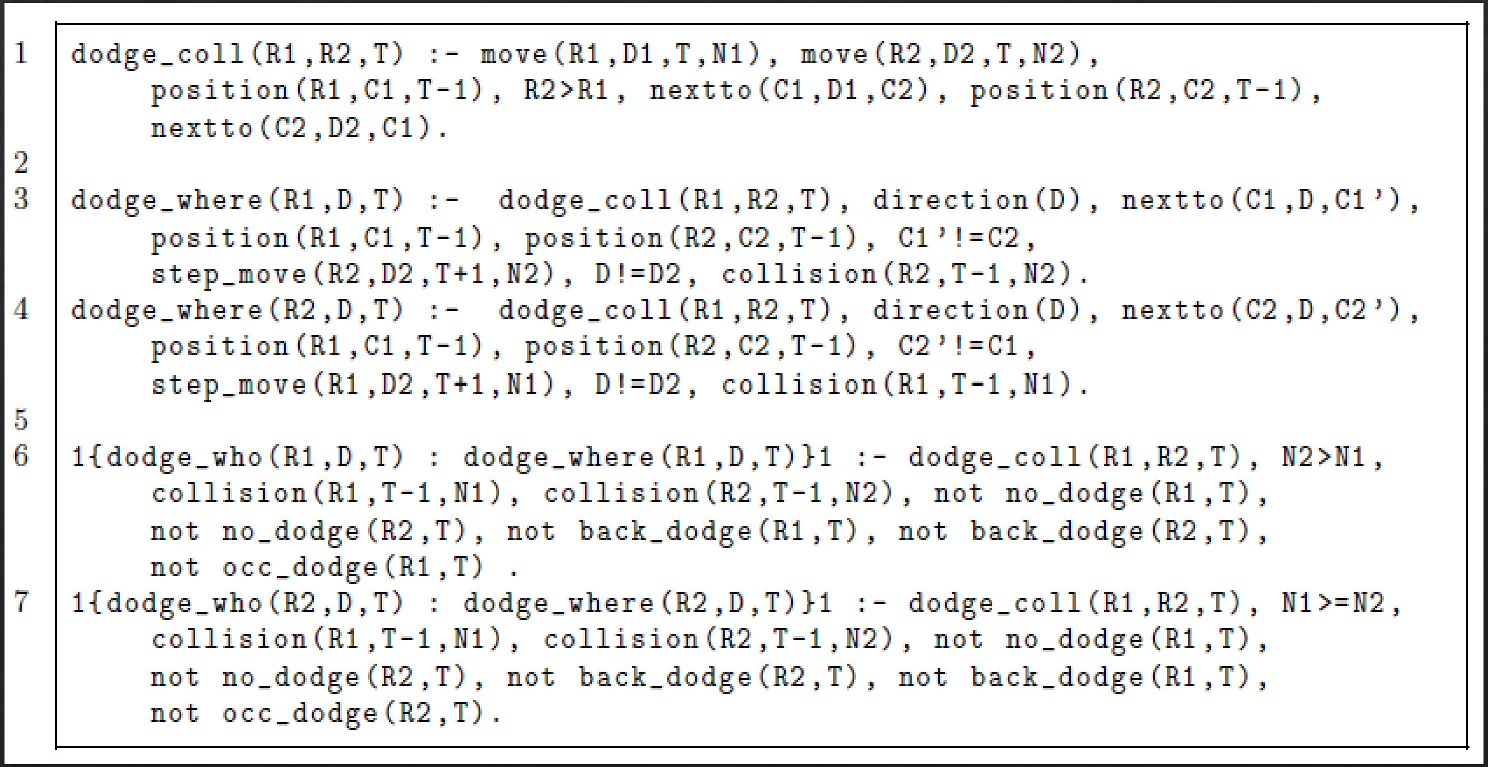
Details of the Merger

- 2.1 Basics
- 2.2 Use cases
  - 2.2.1 vertex collision
  - 2.2.2 edge collision

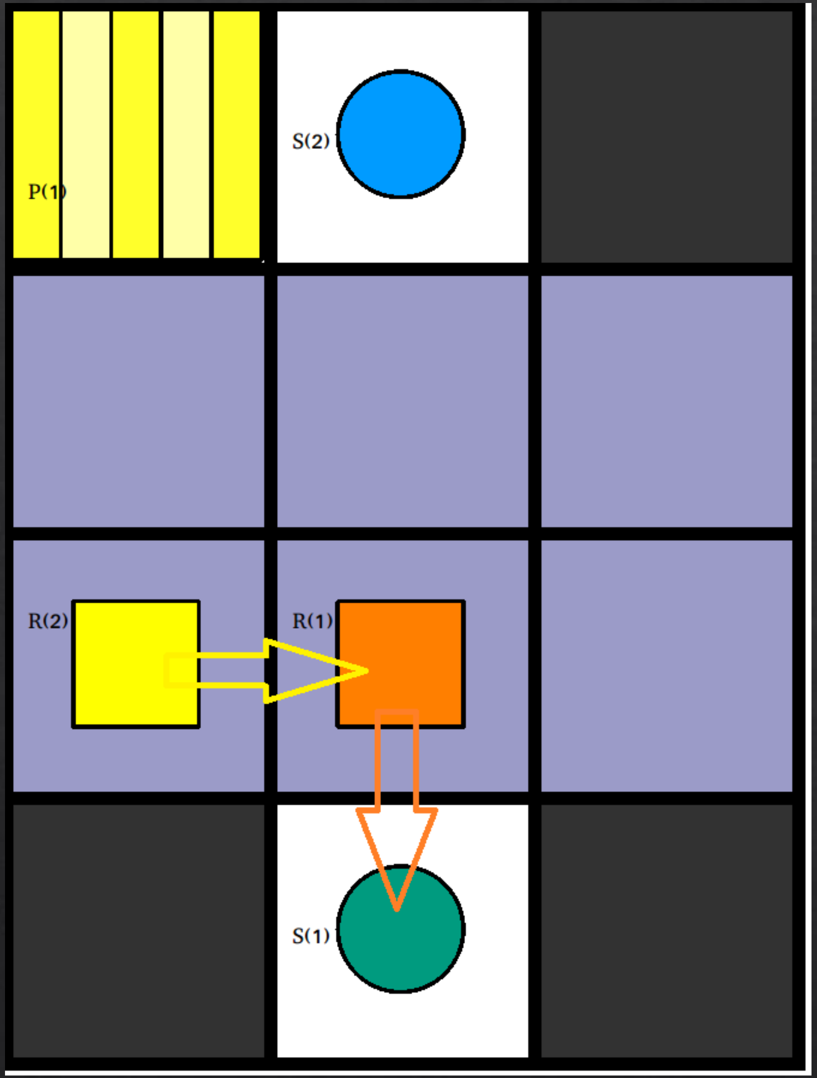


Edge collision

- dodge_coll/3
- dodge_where/3
- dodge_who/3

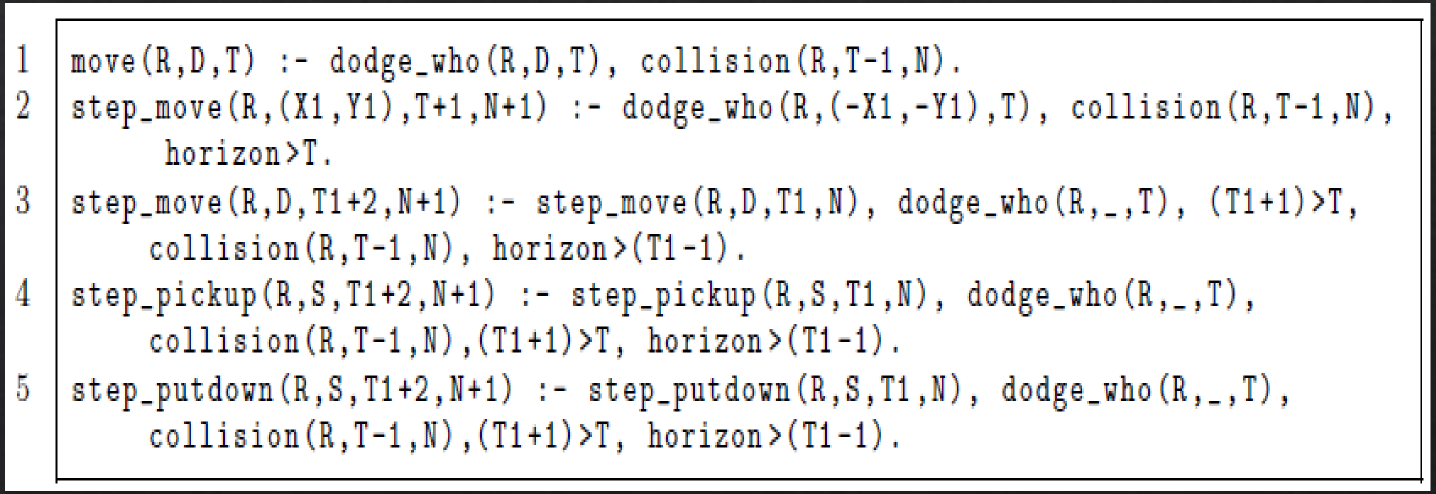


```
dodge_coll(R1,R2,T) :- move(R1,D1,T,N1), move(R2,D2,T,N2),
    position(R1,C1,T-1), R2>R1, nextto(C1,D1,C2), position(R2,C2,T-1),
    nextto(C2,D2,C1).

dodge_where(R1,D,T) :-  dodge_coll(R1,R2,T), direction(D), nextto(C1,D,C1'),
    position(R1,C1,T-1), position(R2,C2,T-1), C1'!=C2,
    step_move(R2,D2,T+1,N2), D!=D2, collision(R2,T-1,N2).
dodge_where(R2,D,T) :-  dodge_coll(R1,R2,T), direction(D), nextto(C2,D,C2'),
    position(R1,C1,T-1), position(R2,C2,T-1), C2'!=C1,
    step_move(R1,D2,T+1,N1), D!=D2, collision(R1,T-1,N1).

1{dodge_who(R1,D,T) : dodge_where(R1,D,T)}1 :- dodge_coll(R1,R2,T), N2>N1,
    collision(R1,T-1,N1), collision(R2,T-1,N2), not no_dodge(R1,T),
    not no_dodge(R2,T), not back_dodge(R1,T), not back_dodge(R2,T),
    not occ_dodge(R1,T) .
1{dodge_who(R2,D,T) : dodge_where(R2,D,T)}1 :- dodge_coll(R1,R2,T), N1>=N2,
    collision(R1,T-1,N1), collision(R2,T-1,N2), not no_dodge(R1,T),
    not no_dodge(R2,T), not back_dodge(R2,T), not back_dodge(R1,T),
    not occ_dodge(R2,T).
```

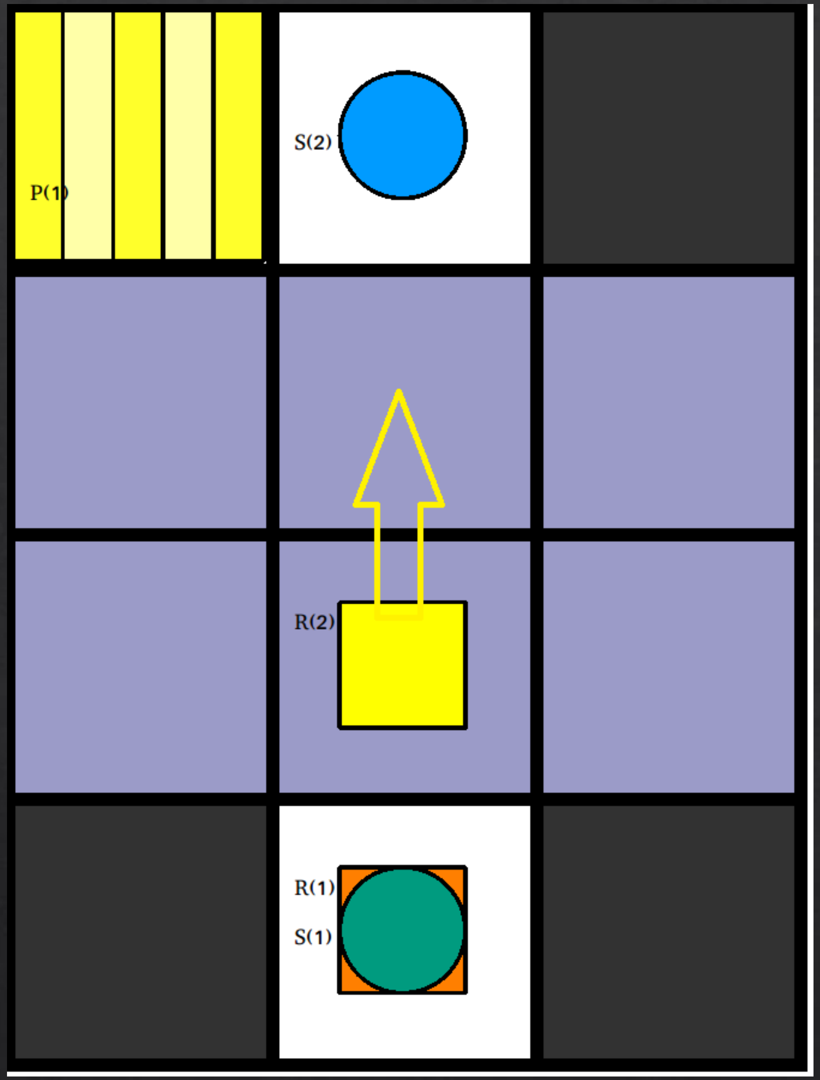


Edge collision

- dodge_coll/3
- dodge_where/3
- dodge_who/3

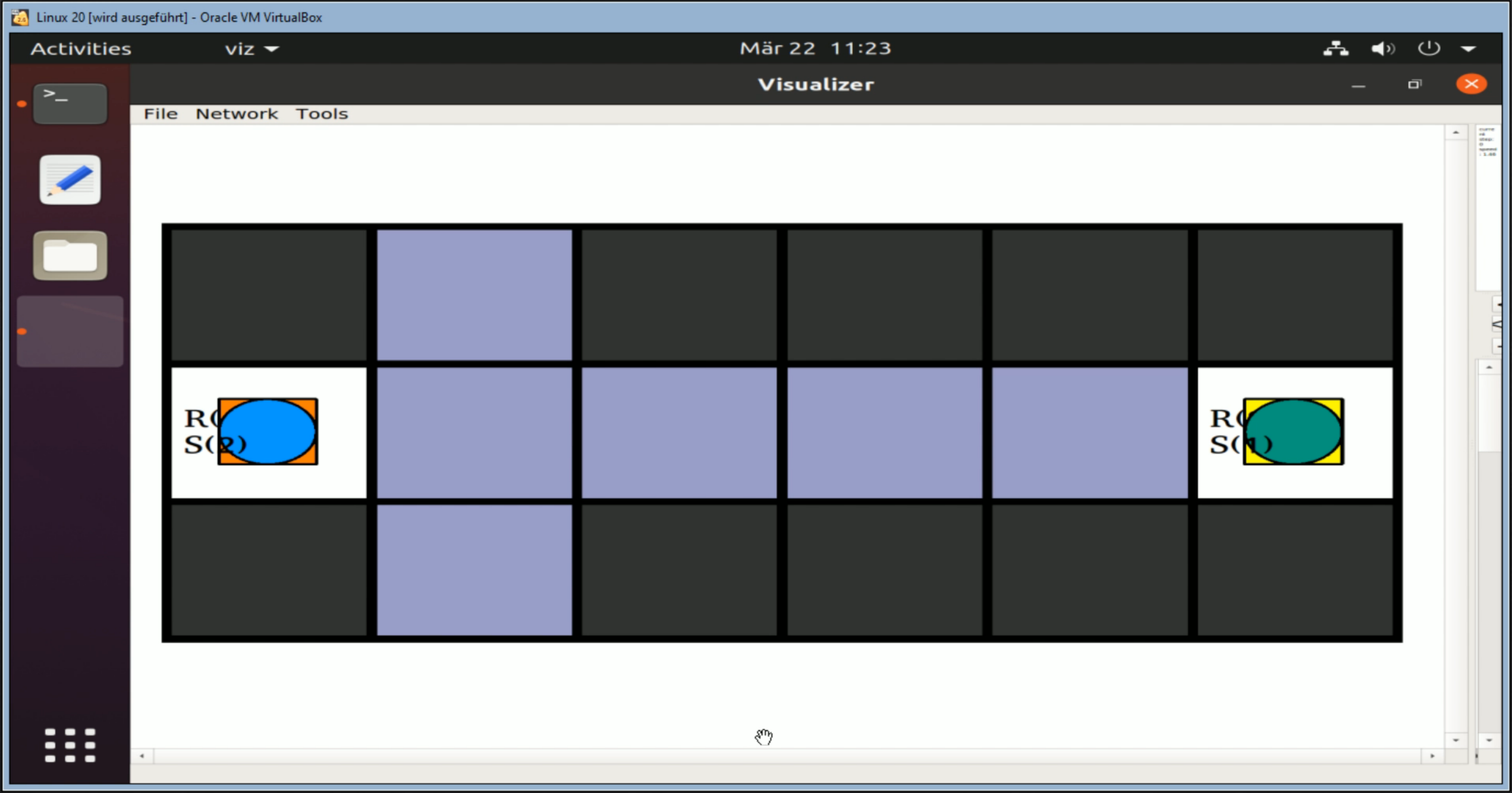


```
move(R,D,T) :- dodge_who(R,D,T), collision(R,T-1,N).
step_move(R,(X1,Y1),T+1,N+1) :- dodge_who(R,(-X1,-Y1),T), collision(R,T-1,N),
      horizon>T.
step_move(R,D,T1+2,N+1) :- step_move(R,D,T1,N), dodge_who(R,_,T), (T1+1)>T,
     collision(R,T-1,N), horizon>(T1-1).
step_pickup(R,S,T1+2,N+1) :- step_pickup(R,S,T1,N), dodge_who(R,_,T),
     collision(R,T-1,N),(T1+1)>T, horizon>(T1-1).
step_putdown(R,S,T1+2,N+1) :- step_putdown(R,S,T1,N), dodge_who(R,_,T),
     collision(R,T-1,N),(T1+1)>T, horizon>(T1-1).
```



Edge collision

- dodge_coll/3
- dodge_where/3
- dodge_who/3


Linux 20 [wird ausgeführt] - Oracle VM VirtualBox
Activities
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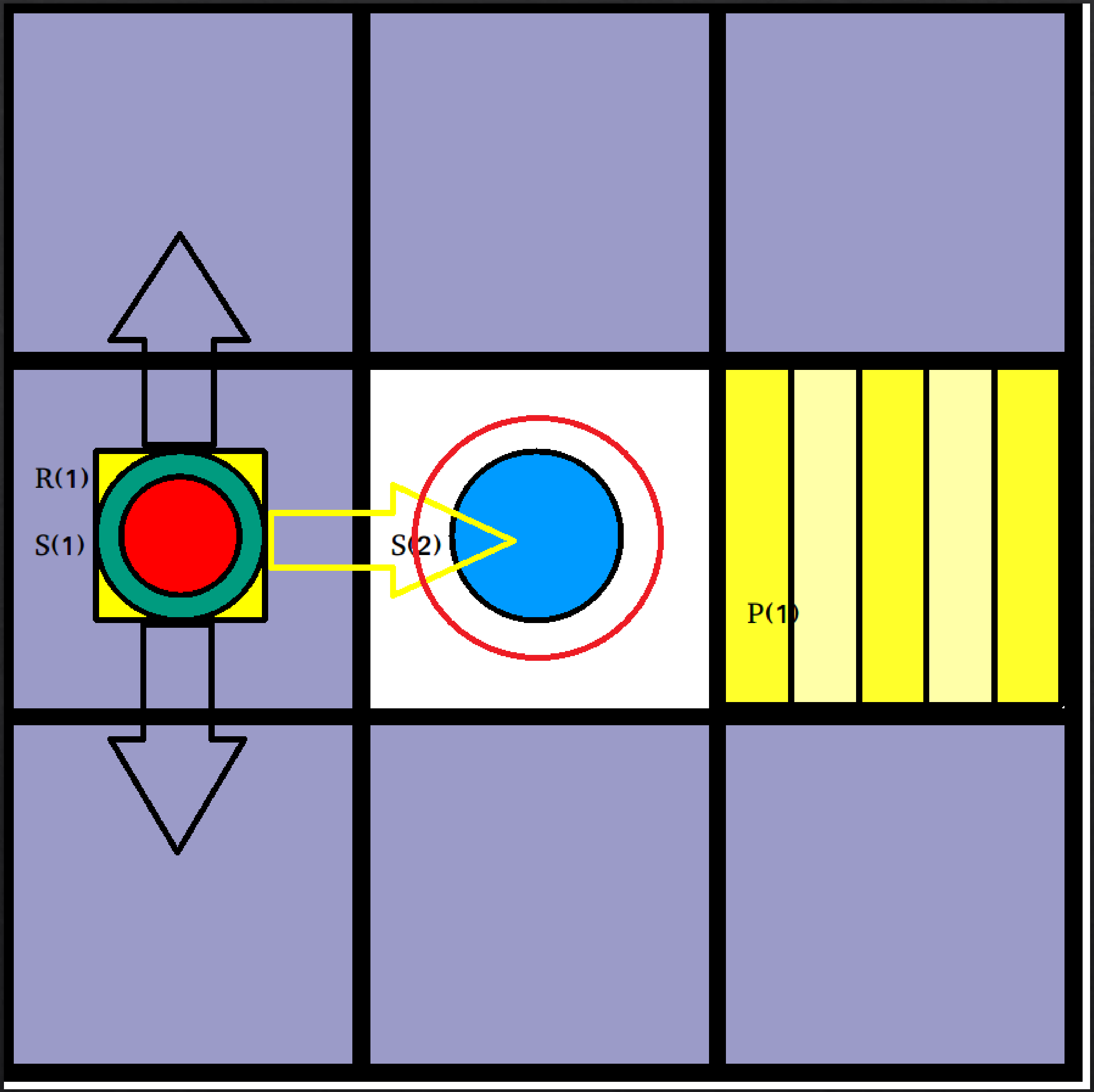
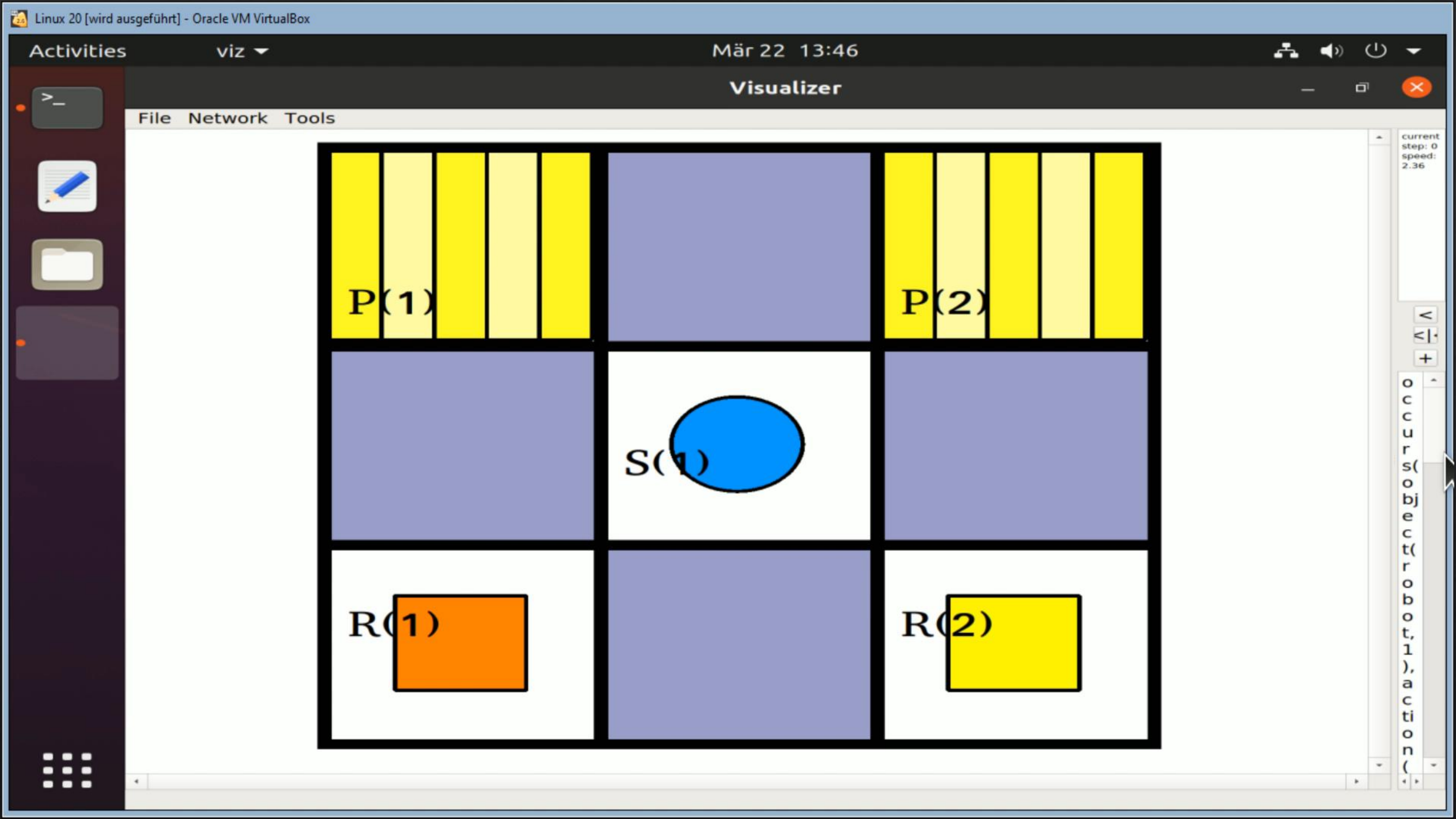
Mär 22 11:23
Visualizer
File
Network
Tools
R(
S(2)
R(
S(1)

Details of the Merger

- 2.1 Basics
- 2.2 Use cases
  - 2.2.1 vertex collision
  - 2.2.2 edge collision
  - 2.2.3 issues of the B domain


R(1)
S(1)
S(2)
P(1)



```
current
step: 0
speed:
2.36
```

```
occurs(object(robot,1),action(
```

Results and Comparison

B. Group 1	Group 1 (Adrian)	Group 2 (Marcus)	Group 3 (Niklas)	Group 4 (Tarek)	Group 5 (Tom)	Horizon	#Robots
1	0.027s	0.457s	0.034s	0.058s	0.018s	5	2
2	0.125s	UNSAT	0.017s	UNSAT	0.016s	3	4
3	209.25	2.903s	0.072s	0.065s	0.094s	7-14	2
4	55.426s	KILLED	0.179	UNSAT	UNSAT	9	8

B. Group 2	Group 1 (Adrian)	Group 2 (Marcus)	Group 3 (Niklas)	Group 4 (Tarek)	Group 5 (Tom)	Horizon	#Robots
1	0.032s	0.972s	0.028s	0.029s	UNSAT	5-7	2
2	0.014s	0.105s	0.012s	0.029s	UNSAT	4	2
3	4.949s	6.666s	0.051s	0.041s	0.107s	6-9	4
4	UNSAT	4.578s	UNSAT	UNSAT	UNSAT	15	2

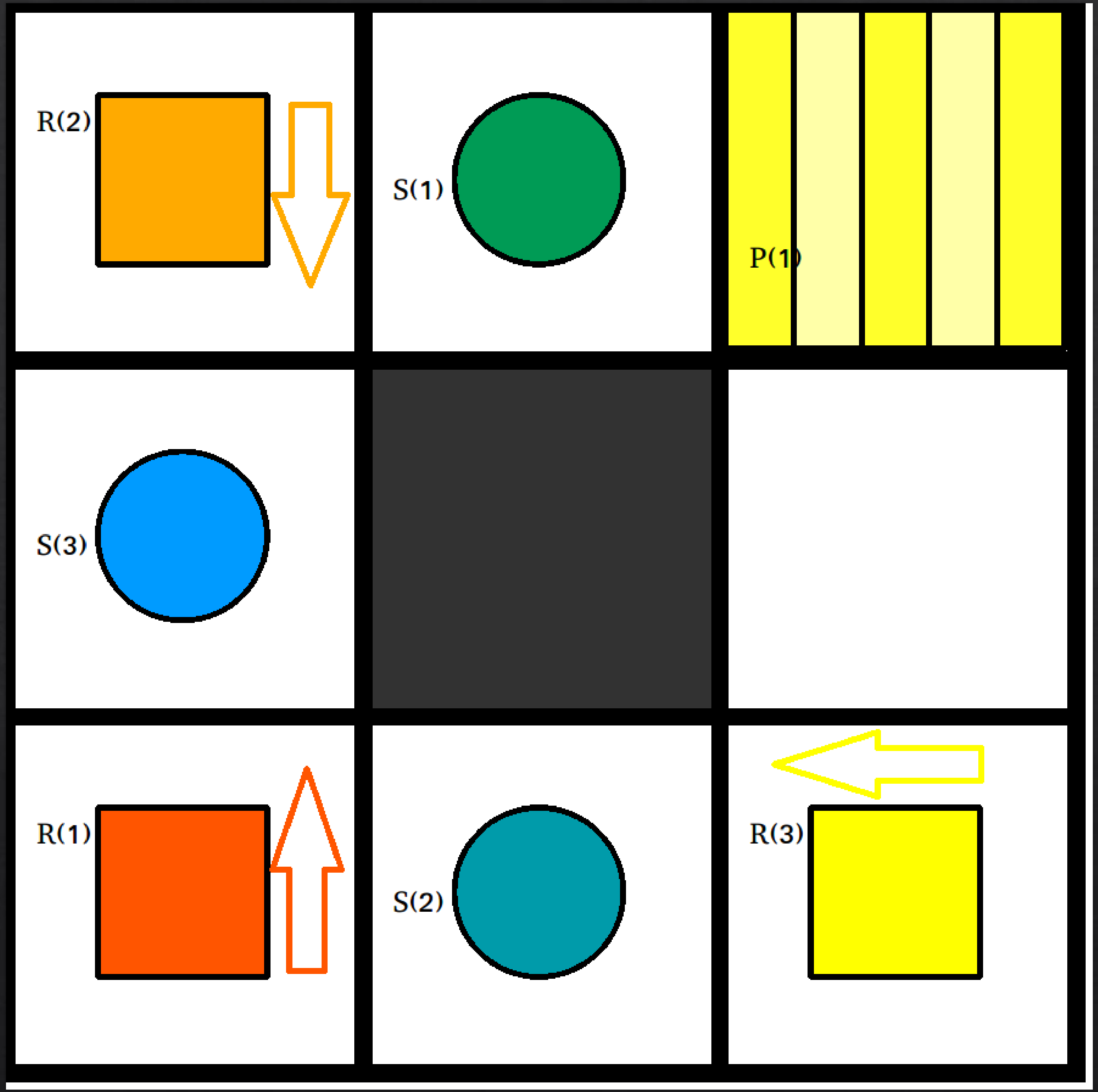
B. Group 3	Group 1 (Adrian)	Group 2 (Marcus)	Group 3 (Niklas)	Group 4 (Tarek)	Group 5 (Tom)	Horizon	#Robots
1	UNSAT	KILLED	0.902s	0.180s	0.309s	12-17	4
2	187.834s	KILLED	0.129s	0.418s	UNSAT	9	8
3	6.442s	KILLED	0.229s	0.450s	UNSAT	10(12)	5
4	419.762s	KILLED	0.229s	3.433s	UNSAT	21(23)	6

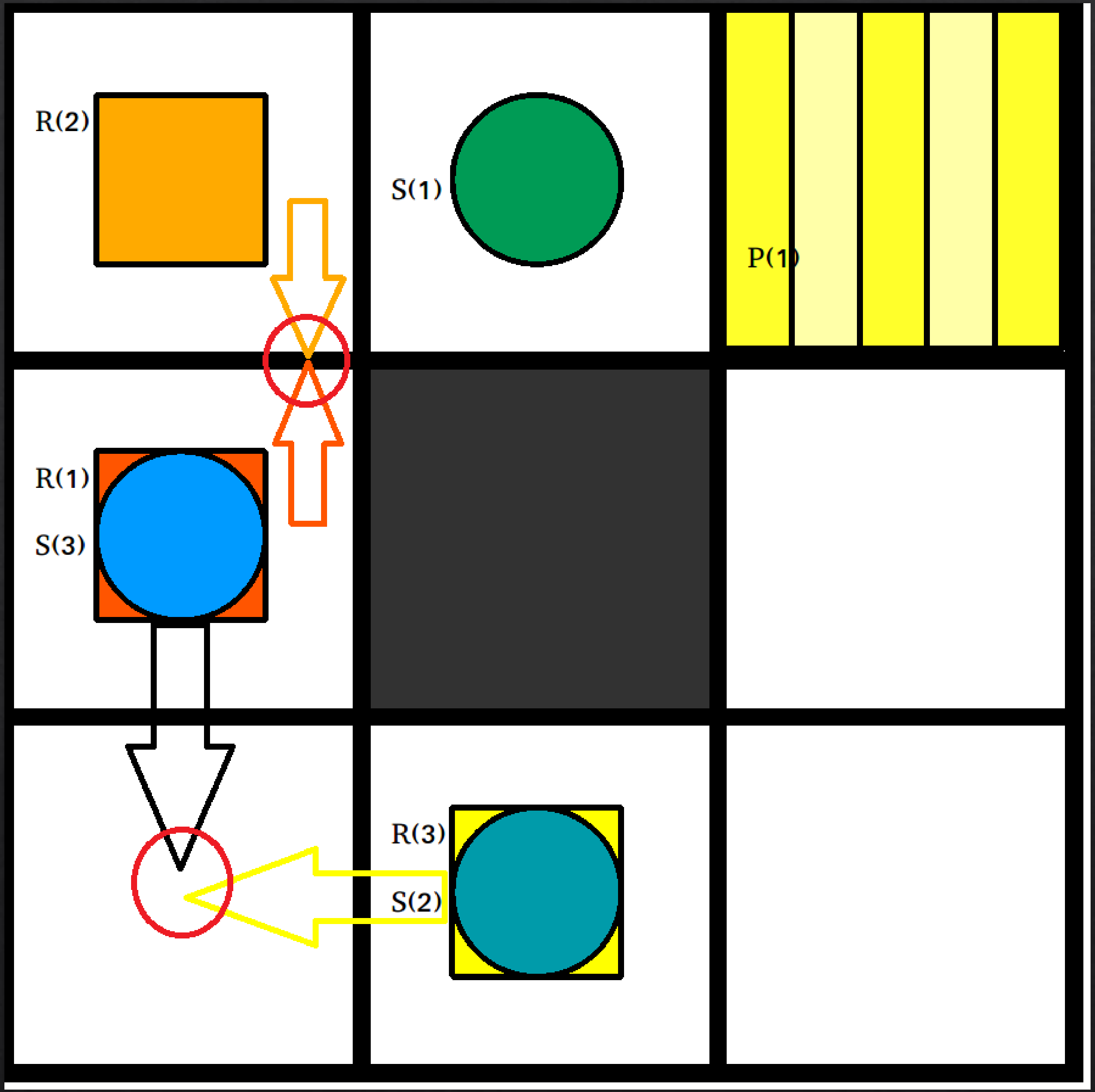
B. Group 4	Group 1 (Adrian)	Group 2 (Marcus)	Group 3 (Niklas)	Group 4 (Tarek)	Group 5 (Tom)	Horizon	#Robots
1	UNSAT	UNSAT	UNSAT	0.037s	UNSAT	5	3
2	KILLED	UNSAT	0.442s	0.352s	UNSAT	19	2
3	0.350s	UNSAT	0.058s	0.191s	0.191s	9(14)	3
4	1.065s	7.669s	0.084s	0.064	0.152s	15-16	2

B. Group 5	Group 1 (Adrian)	Group 2 (Marcus)	Group 3 (Niklas)	Group 4 (Tarek)	Group 5 (Tom)	Horizon	#Robots
1	UNSAT	UNSAT	UNSAT	0.047s	0.127s	6-10	4
2	0.070s	3.000s	0.032s	0.024s	0.060s	4	3
3	KILLED	KILLED	KILLED	UNSAT	KILLED	40	50
4	KILLED	KILLED	KILLED	UNSAT	KILLED	100	30

Conclusion

- General
- Special benchmarks and their problems


R(2)
S(1)
P(1)
S(3)
R(1)
S(2)
R(3)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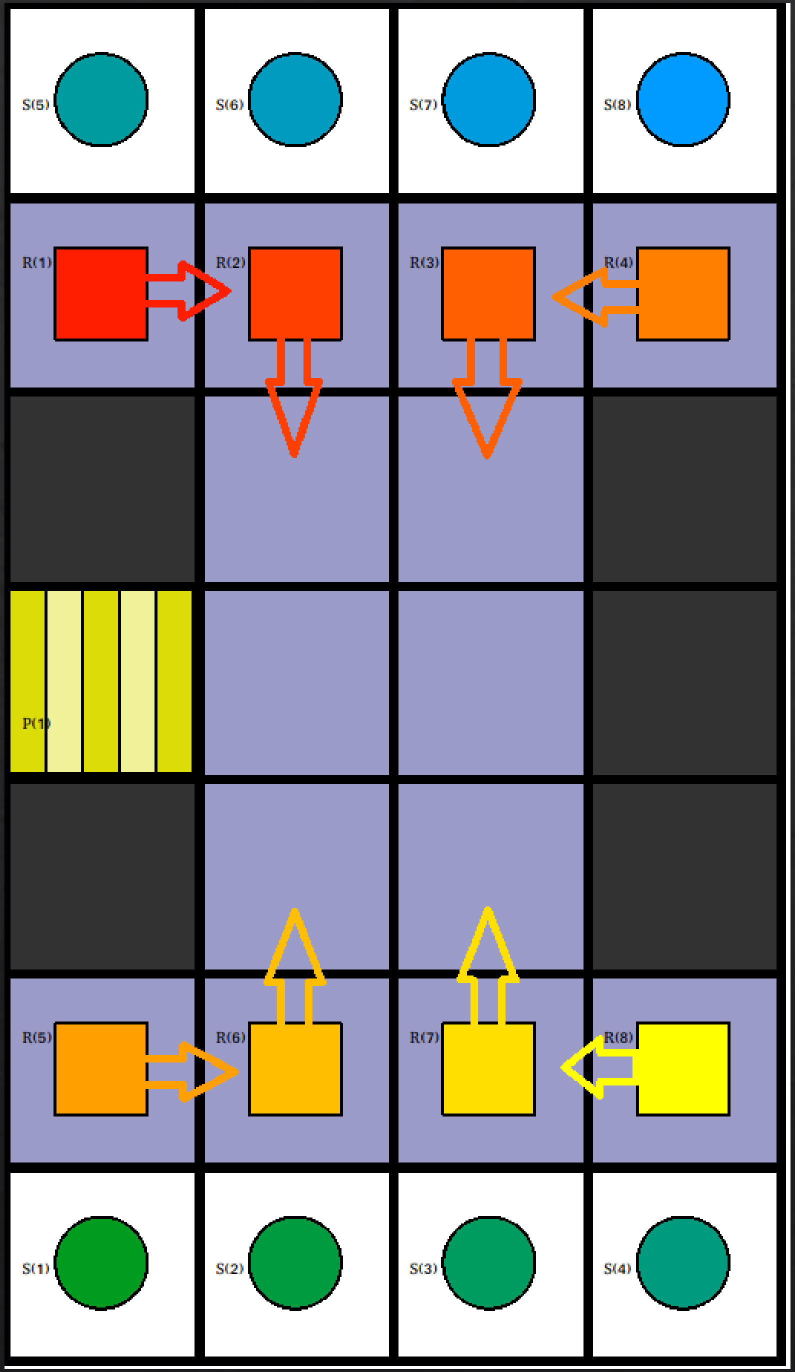
P(1)
R(1)
S(3)
R(3)
S(2)


S(5)
S(6)
S(7)
S(8)
R(1)
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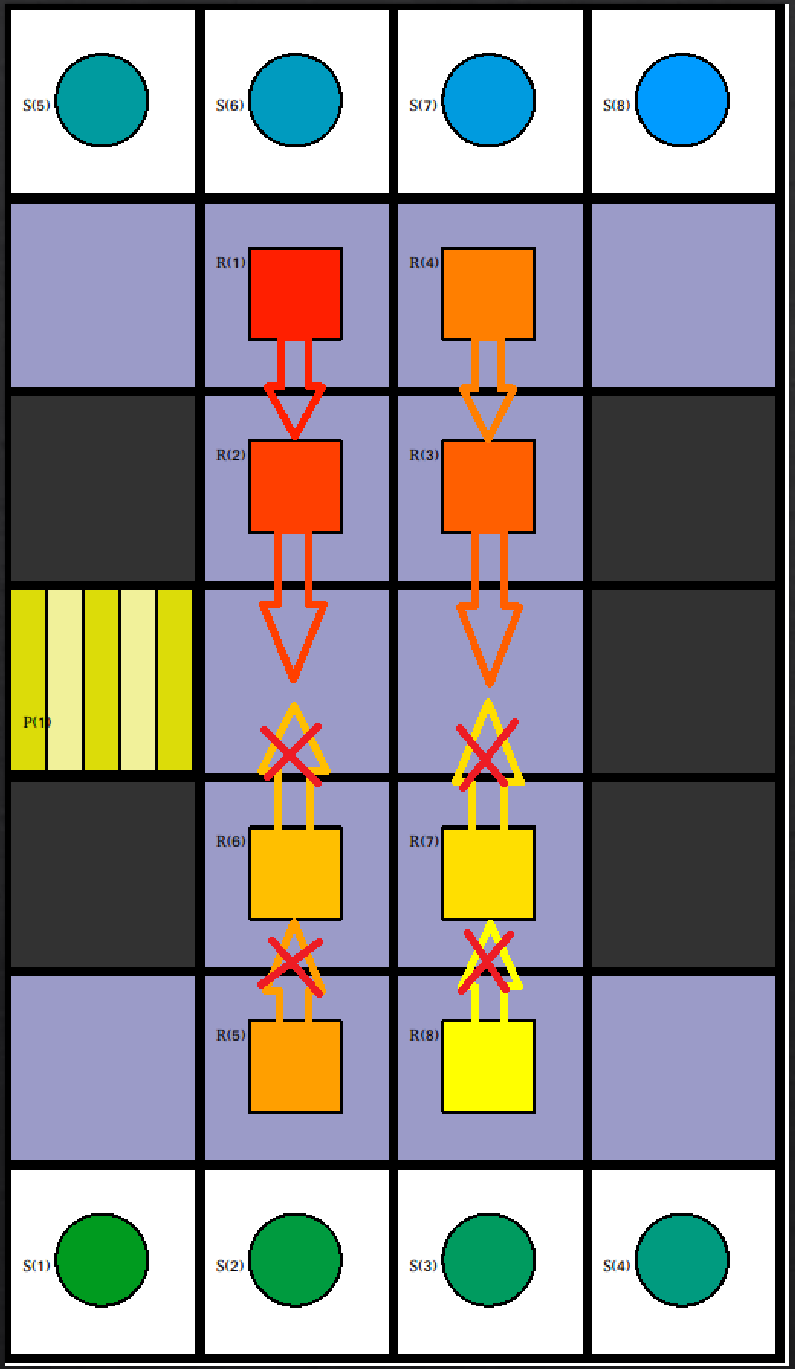
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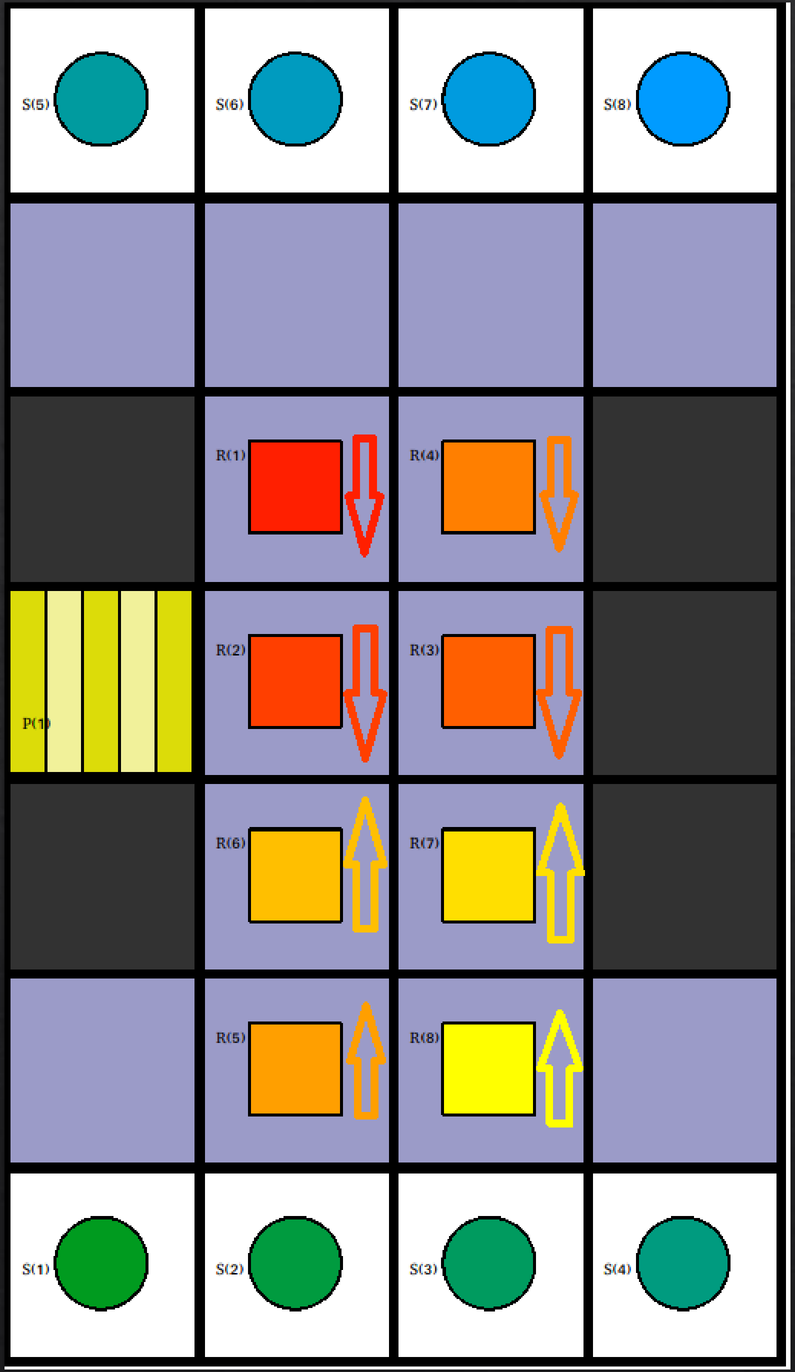
S(5)
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R(8)
S(1)
S(2)
S(3)
S(4)

Plans going forward

- Fixes for known “bugs”
- shelf collisions
- Adding new features

Questions?

References

- Group 2 (Marcus & Marcus) : https://github.com/Zard0c/ProjektMAPF
- Group 1 (Adrian) : https://github.com/salewsky/Plan-Merging
- Group 3 (Niklas & Marius) : https://github.com/NikKaem/mapf-project
- Group 4 (Tarek) : https://github.com/tramadan-up/asprilo-project
- Group 5 (Tom, Julian, Hannes) : https://github.com/tzschmidt/PlanMerger
- Experimenting with robotic intra-logistics domains : https://arxiv.org/abs/1804.10247
- Picture 1: Experimenting with robotic intra-logistics domains, page 7
- Picture 2-4 : Group 2, benchmark 5
- Picture 5-7 : Group 2, benchmark 6
- Picture 8 : small benchmark made for this presentation
- Picture 9-11: Group 4, shared benchmark 1
- Picture 12-14: Group 3, benchmark 6
- Table 1-5: Group 2 report paper, page 26 – 28
- Video 1: video on benchmark 16_mod2 from group 2
- Video 2: video on benchmark 17 from group 2