Hierarchical Plan Generation and Selection for Shortest Plans based on Experienced Execution Duration

Using Parallel Plan Execution

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April 7, 2015

Outline

Introduction

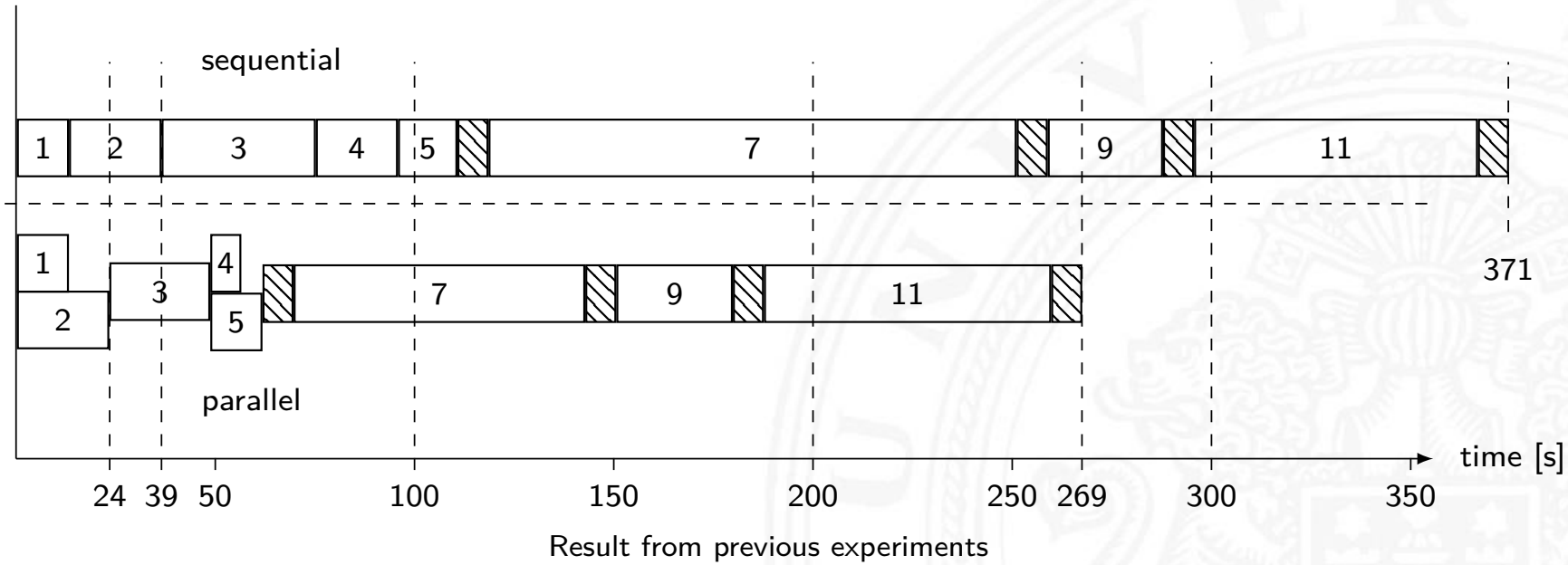
Motivation

- HTN Planing
- Improve execution duration of complex tasks
  - save resources
  - increase efficiency
- Parallel execution
  - improved execution duration

Previous Work

- L. Einig, D. Klimentjew, S. Rockel, L. Zhang, and J. Zhang, "Parallel plan execution and re-planning on a mobile robot using state machines with HTN planning systems," in *ROBIO'13*, pp. 151–157, 2013
- Reduce execution time
  - $\sim$30 % for complex tasks
  - up to 40 % for certain tasks

Previous Work



Result from previous experiments

Objective

- Extract execution duration
- Evaluate generated plans
- Find fastest plan
  - shortest plan based on steps
  - shortest plan based on execution duration
    - sequential
    - parallel

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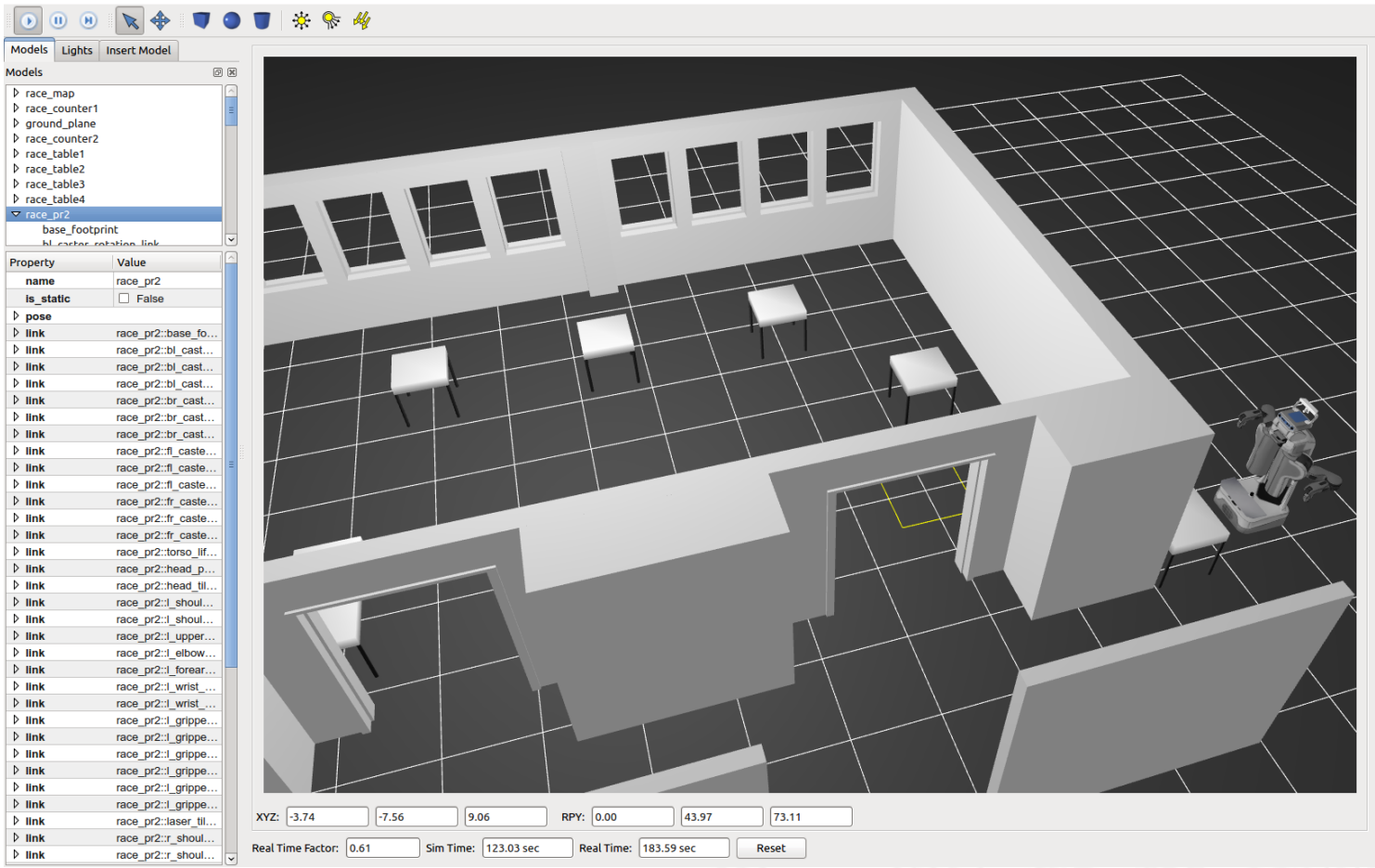
Project Setting

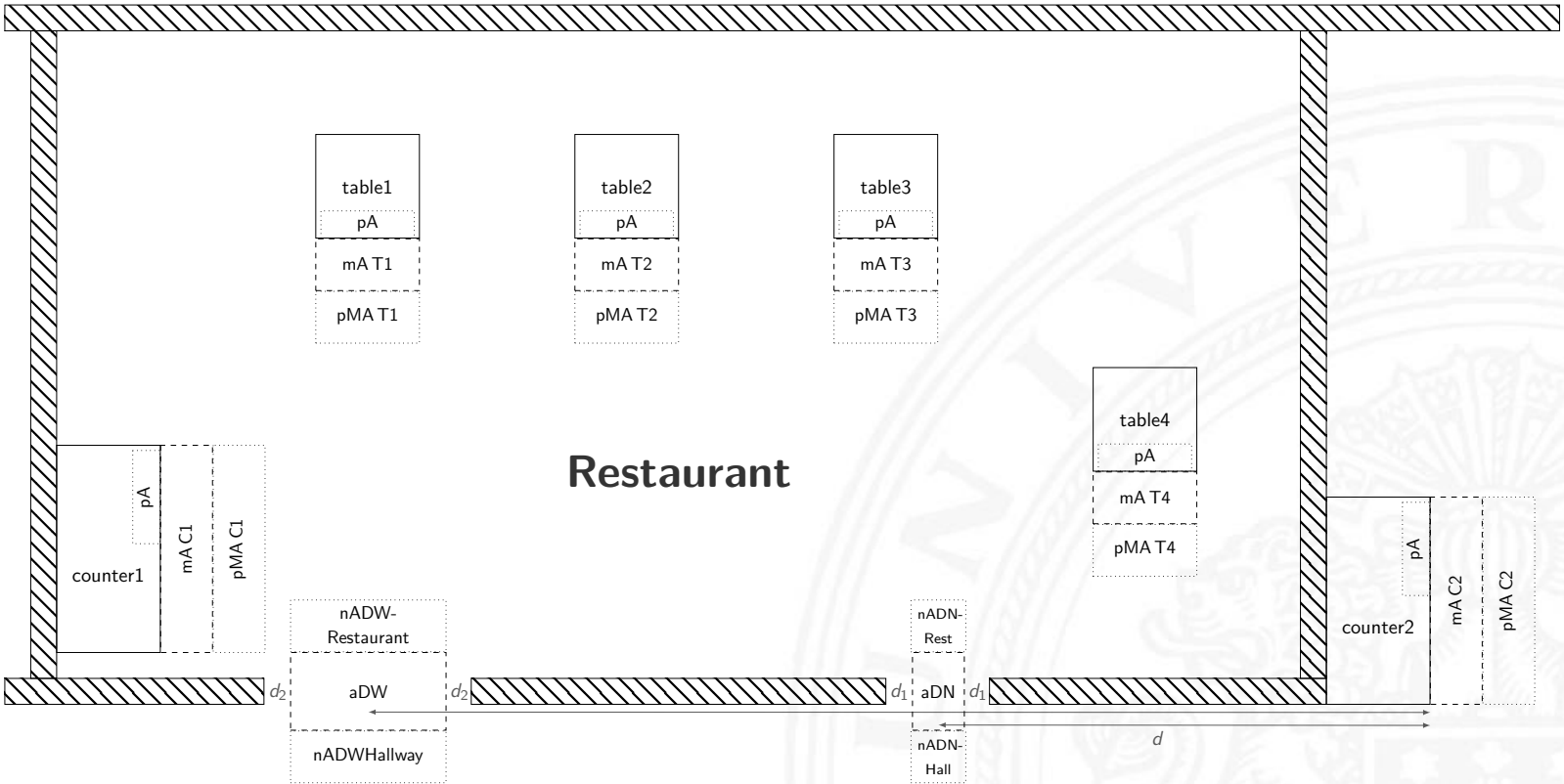
Gazebo



Gazebo Simulator GUI

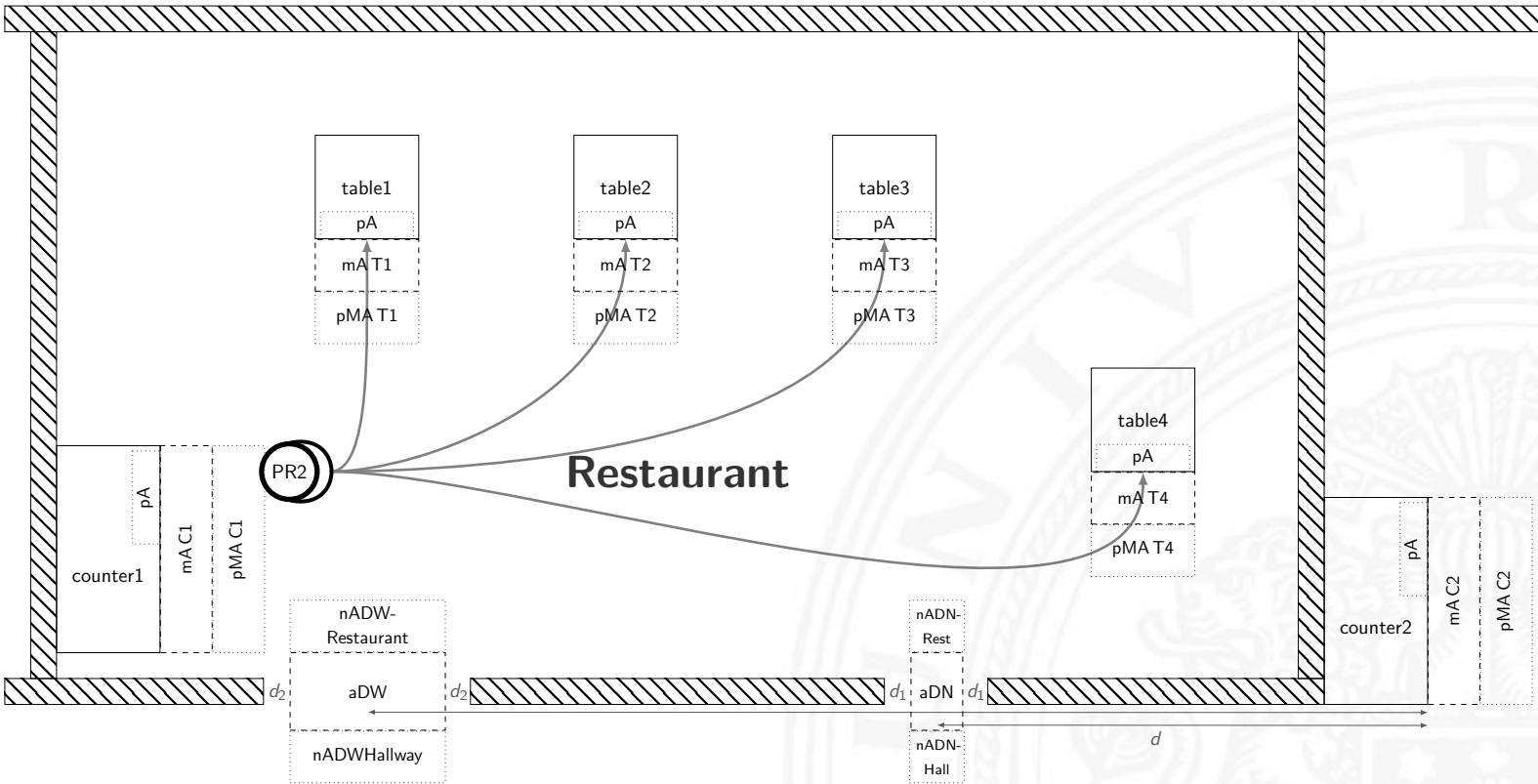
Scenarios

Scenarios



Blueprint of restaurant environment

Attend Table



Sketch of attend table scenario

Attend Table

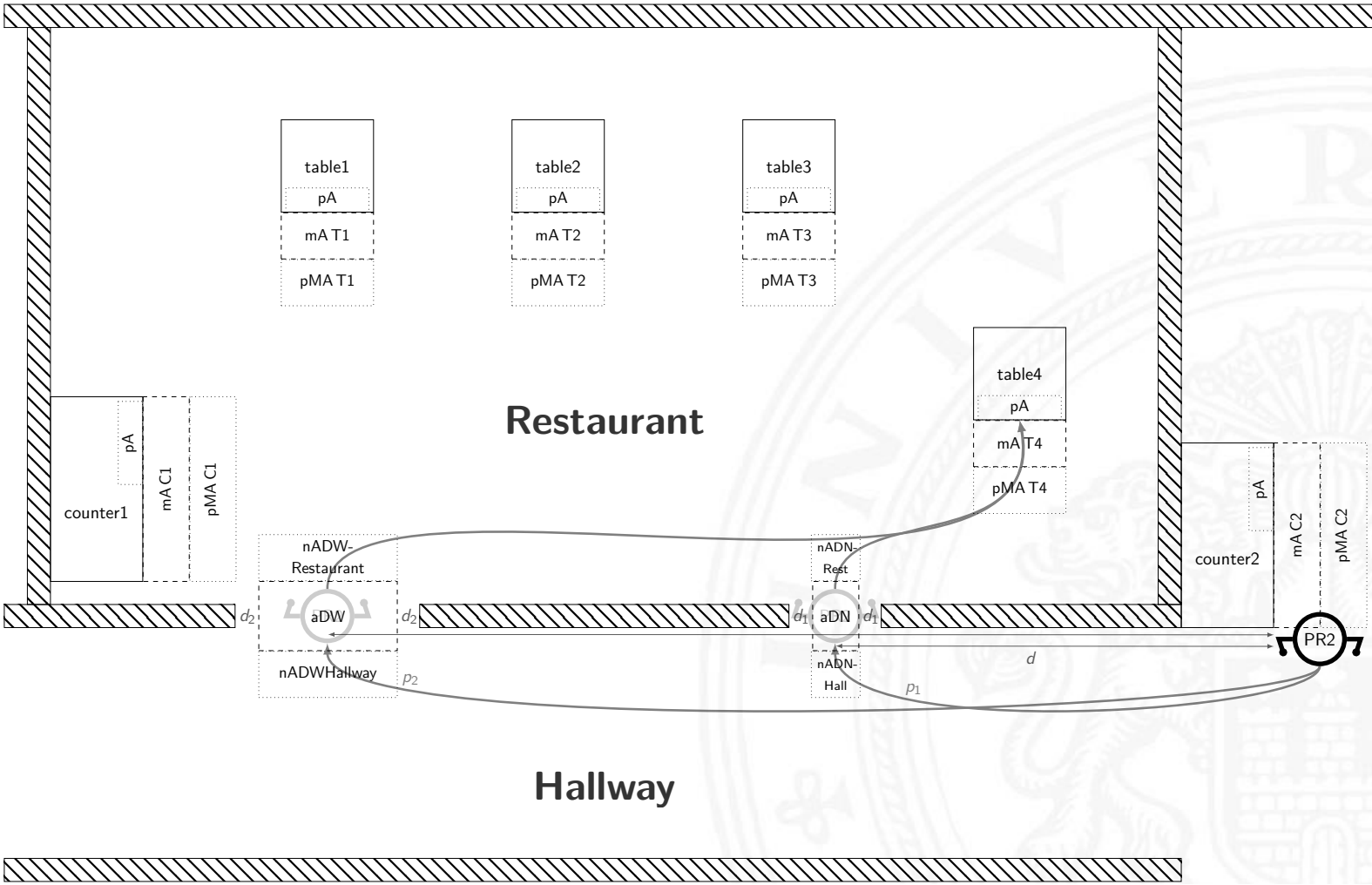
Plan

- Drive to table

Plan

```
!MOVE_BASE_BLIND PREMANIPULATIONAREACOUNTER1
!MOVE_TORSO TORSODOWNPOSTURE
!TUCK_ARMS ARMTUCKEDPOSTURE ARMTUCKEDPOSTURE
!MOVE_BASE TABLE#
```

Door



Sketch of door scenario

Door

Plan

- Drive to table
  - Pass door

Plan for narrow door

```
!MOVE_BASE_BLIND PREMANIPULATIONAREACOUNTER2
!MOVE_TORSO TORSODOWNPOSTURE
!TUCK_ARMS ARMTUCKEDPOSTURE ARMTUCKEDPOSTURE
!MOVE_BASE NEARAREADOORNARROWHALLWAY
!MOVE_BASE_PARAM NEARAREADOORNARROWRESTAURANT SLOW
!MOVE_BASE TABLE4
```

Planning Domain

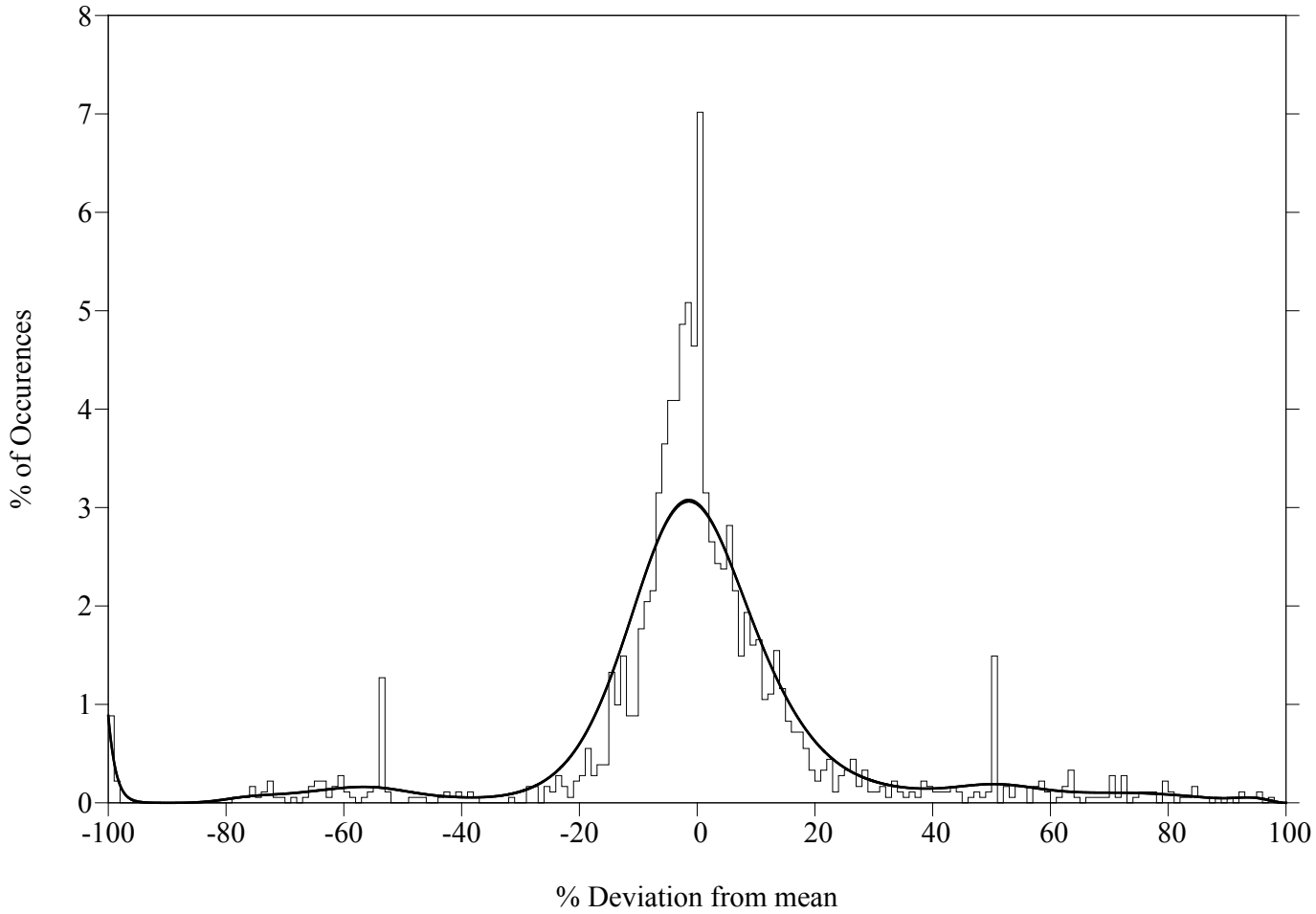
- Domain modifications
  - omit lowering torso
  - fast and slow movement
  - pass doors

Temporal Experience Extractor

Implementation

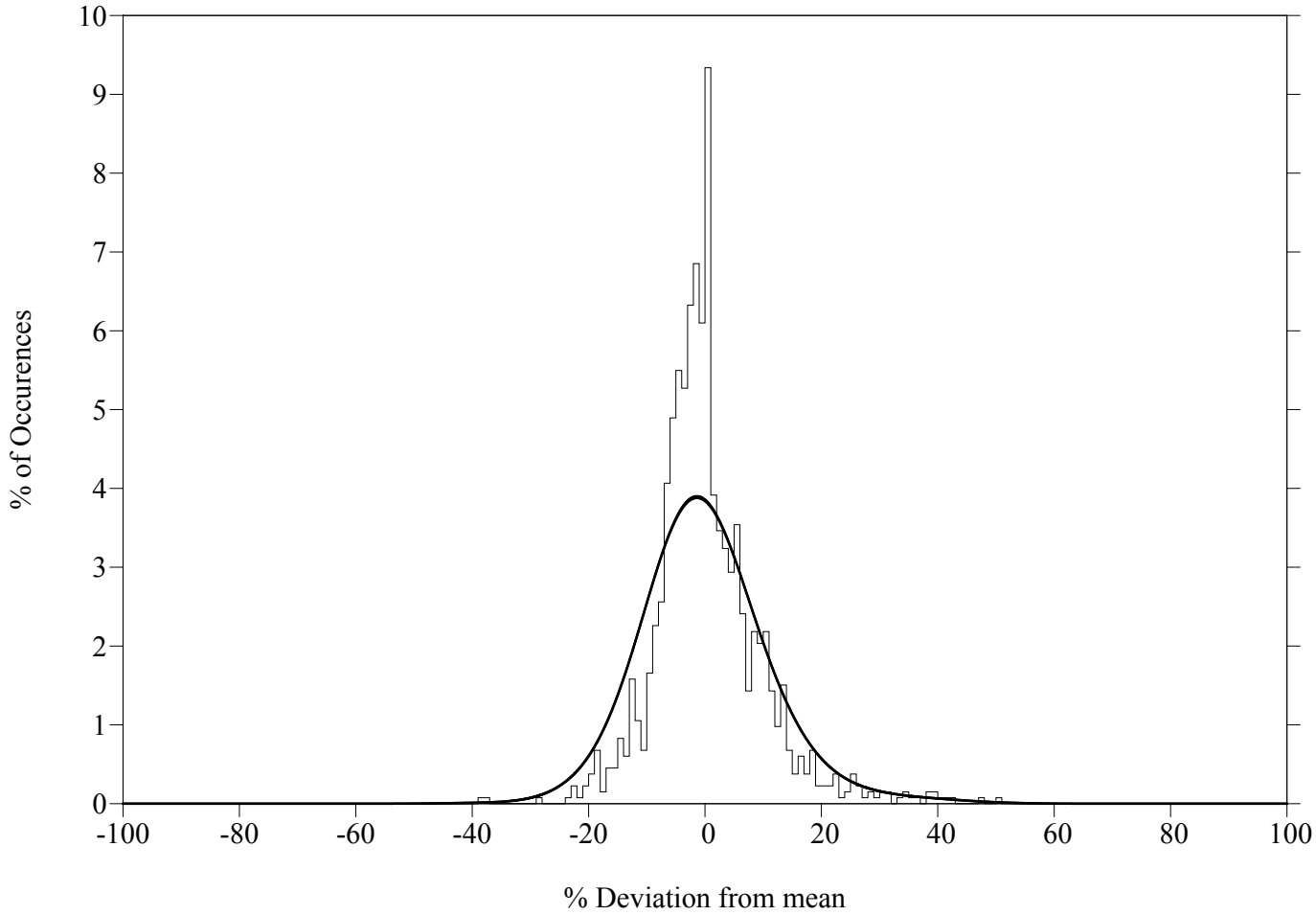
- Three-layer architecture
- **S**tate**MACH**ine
  - task $\rightarrow$ state
- Algorithm
  - limited memory
  - filter outliers
  - return (weighted) average

Evaluation



$>$ 22 time values per operator, 1810 time values in total

Evaluation - filtered

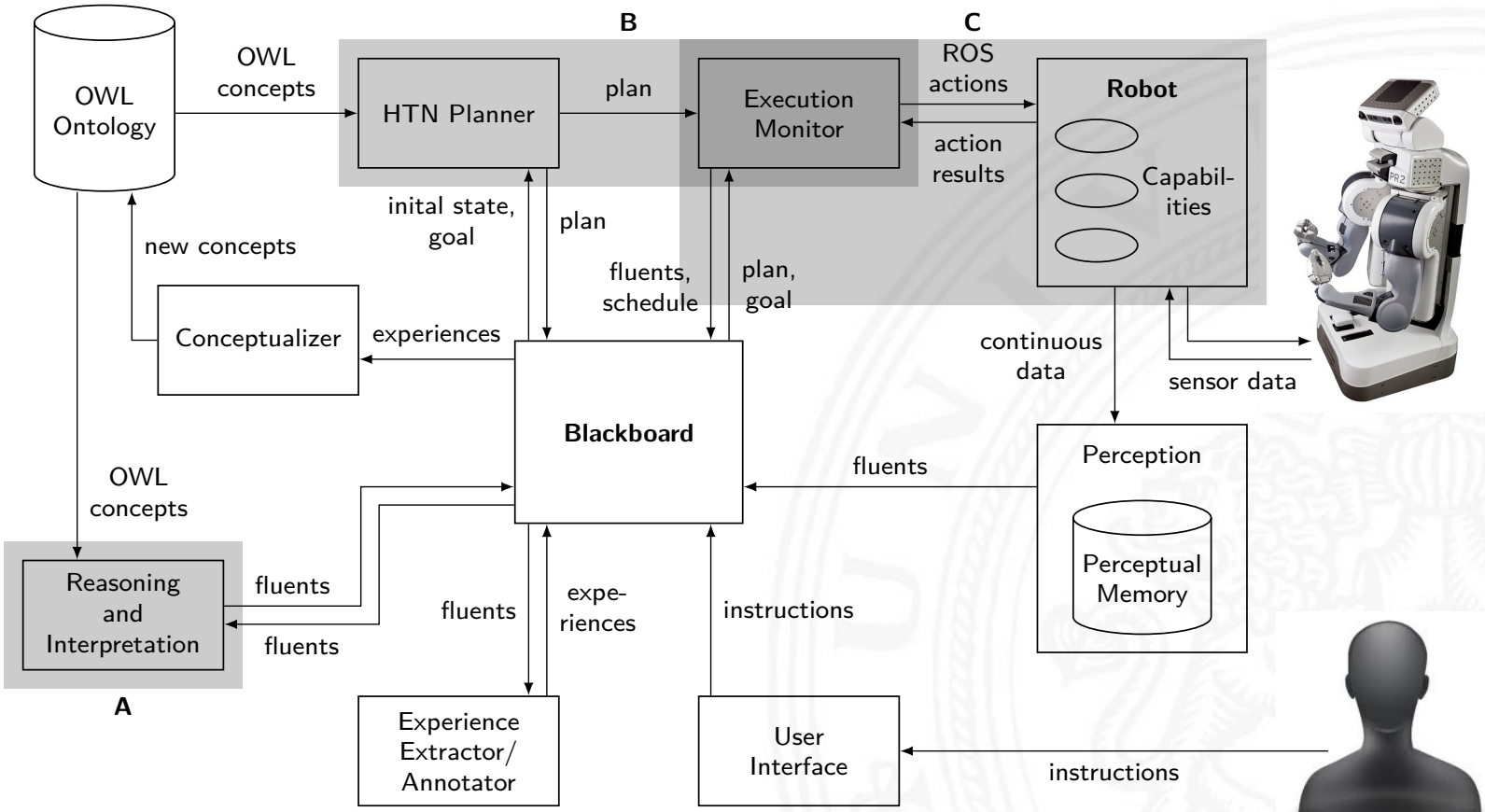


filtered temporal data

Plan Evaluator

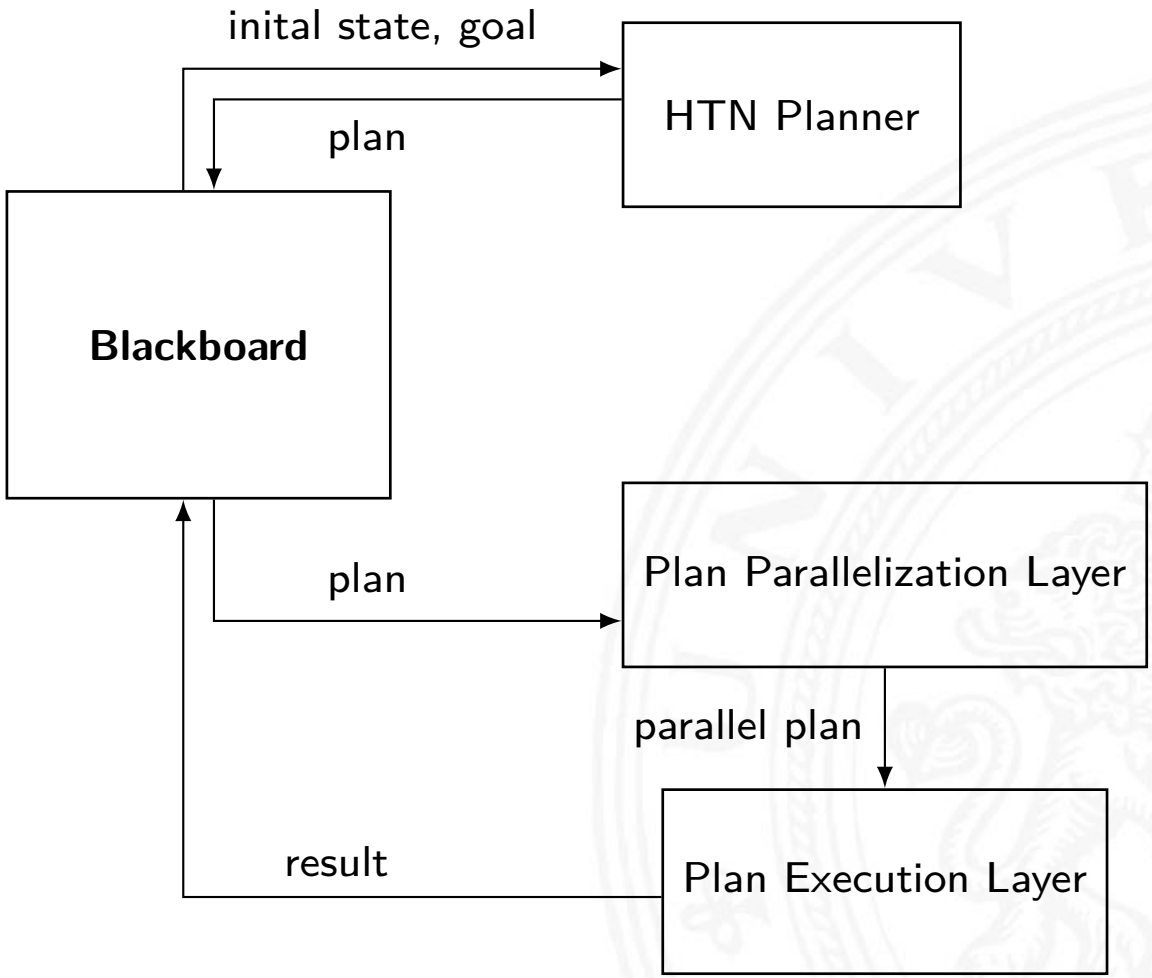
Project Setting

RACE



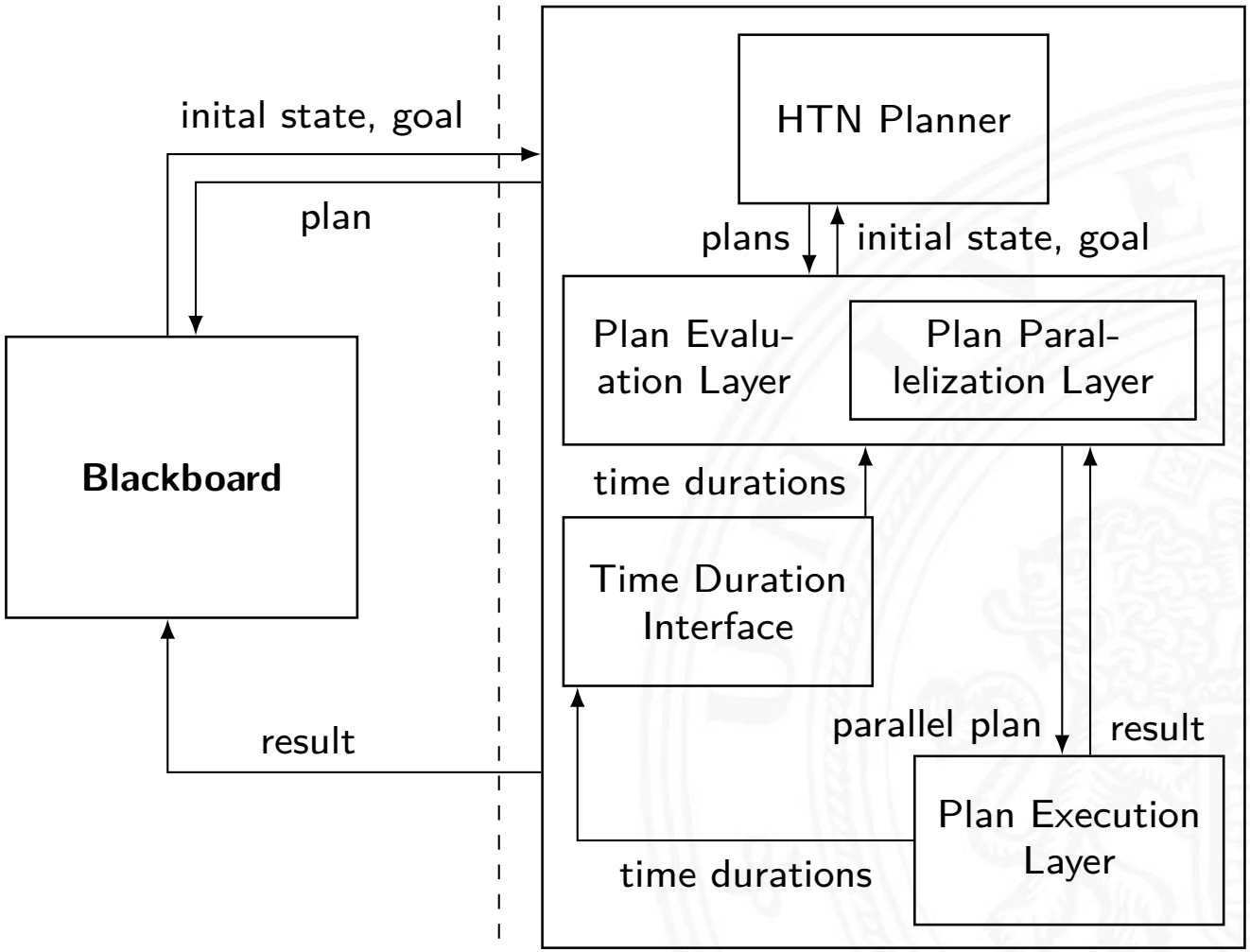
RACE architecture

Foundation



Three-layer architecture

Foundation



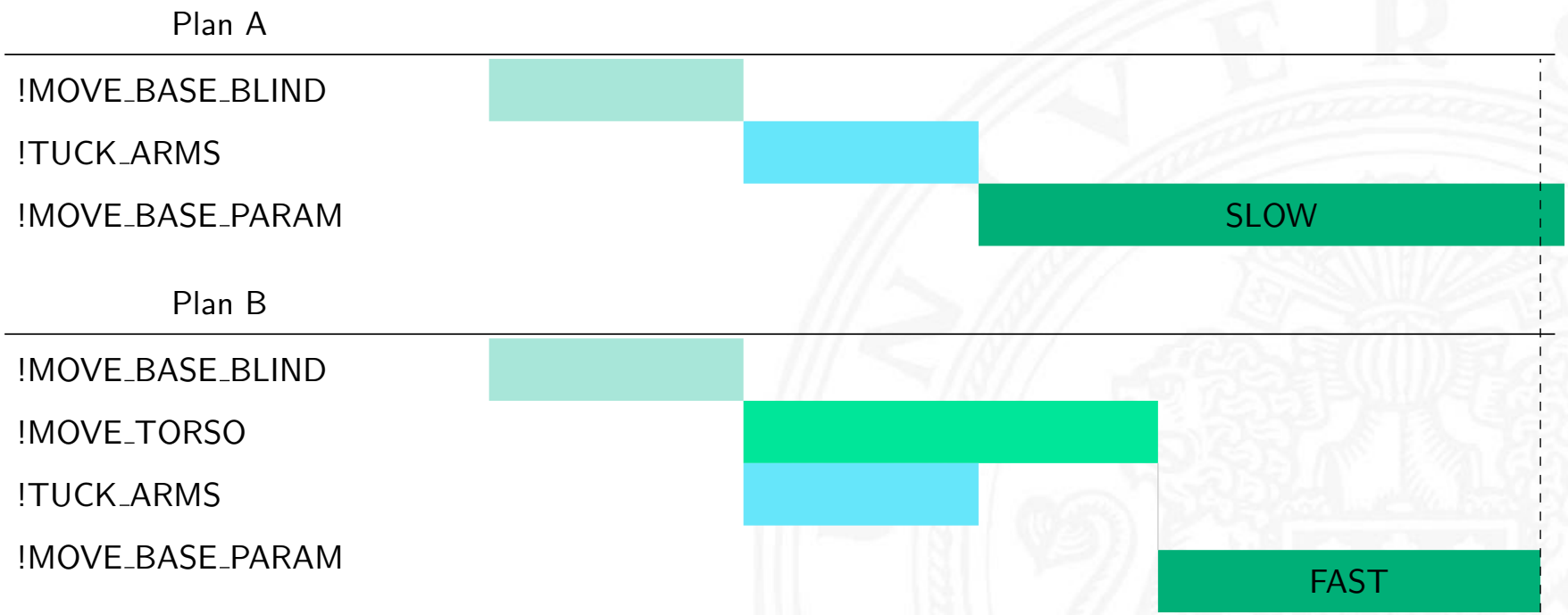
Plan Evaluator architecture

Implementation

- Retrieve all possible plans
- For each plan
  - retrieve plan step cost
  - summate step cost
  - sequential sections
    - sum of all steps
  - parallel sections
    - step with longest duration
- Return shortest plan

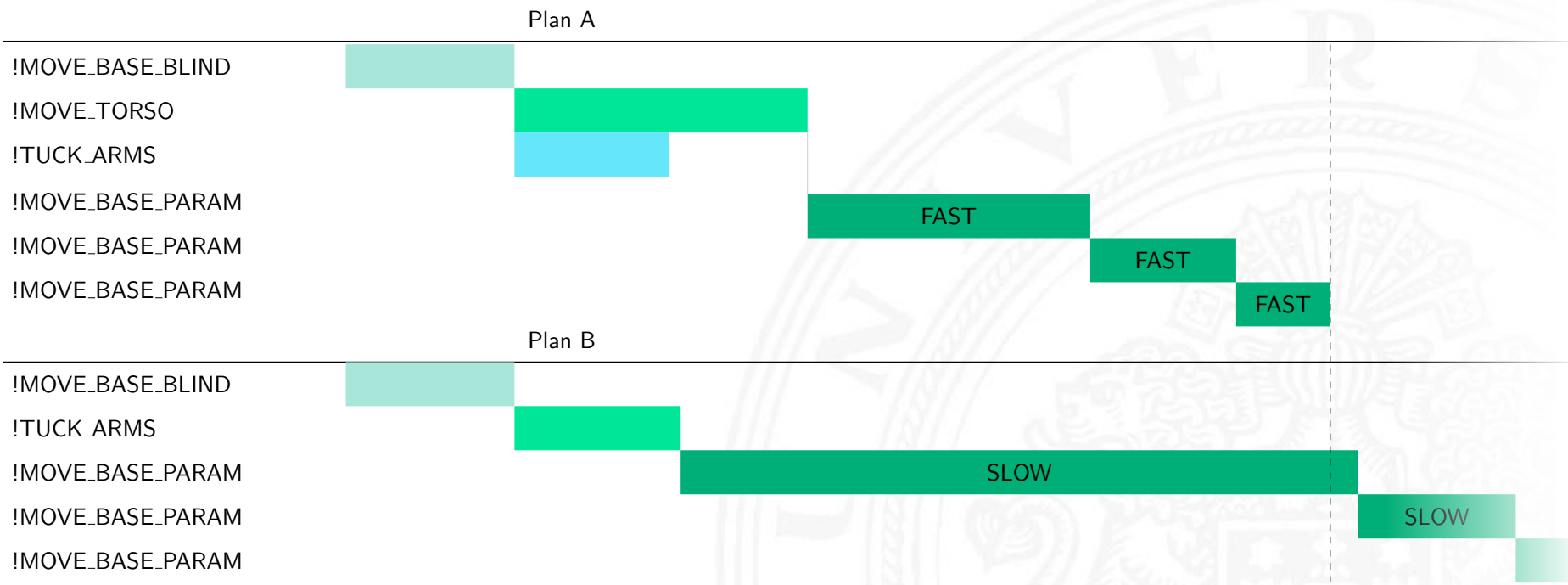
Results

Attend Table



Gantt-chart of attend table results

Door

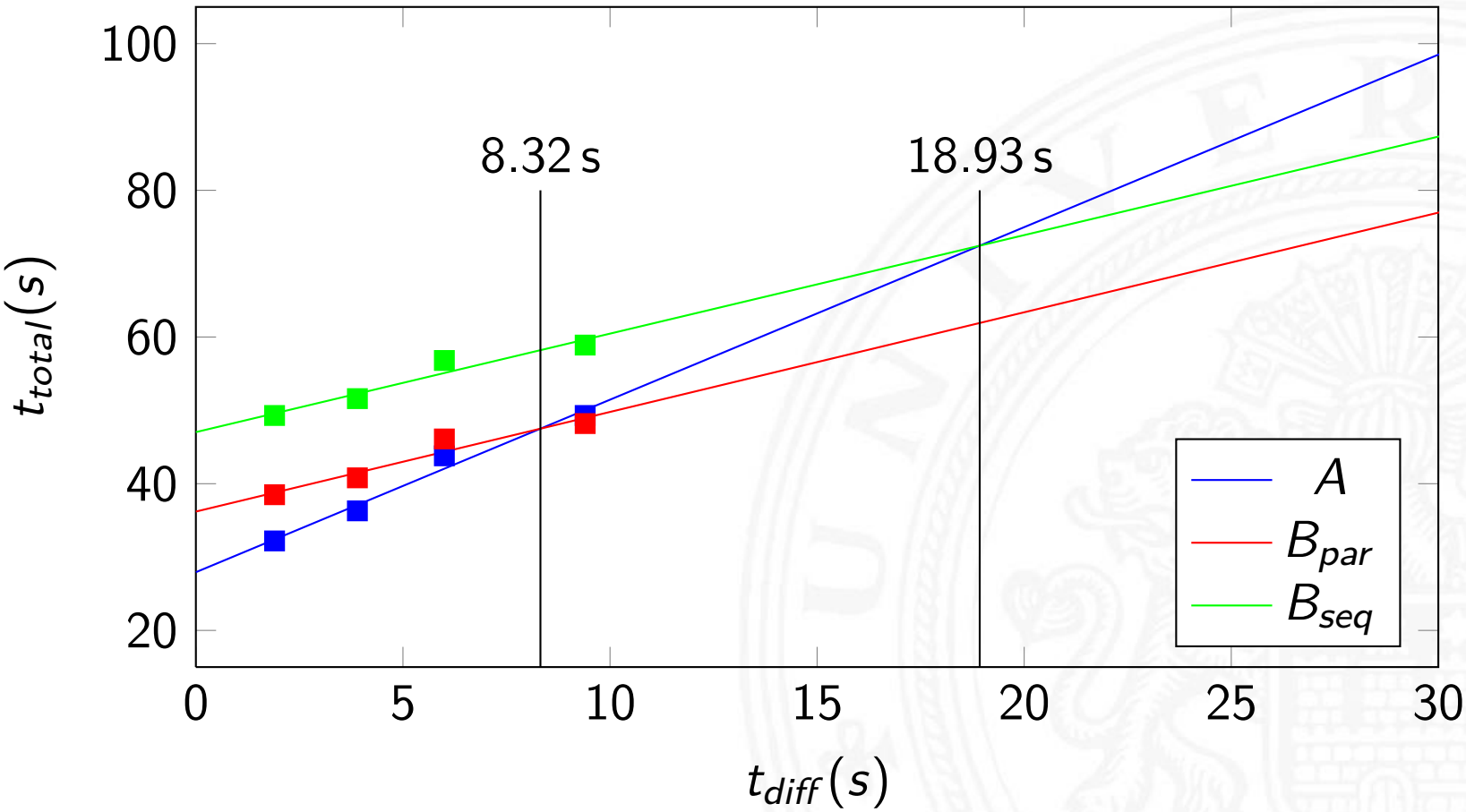


Gantt-chart of door results

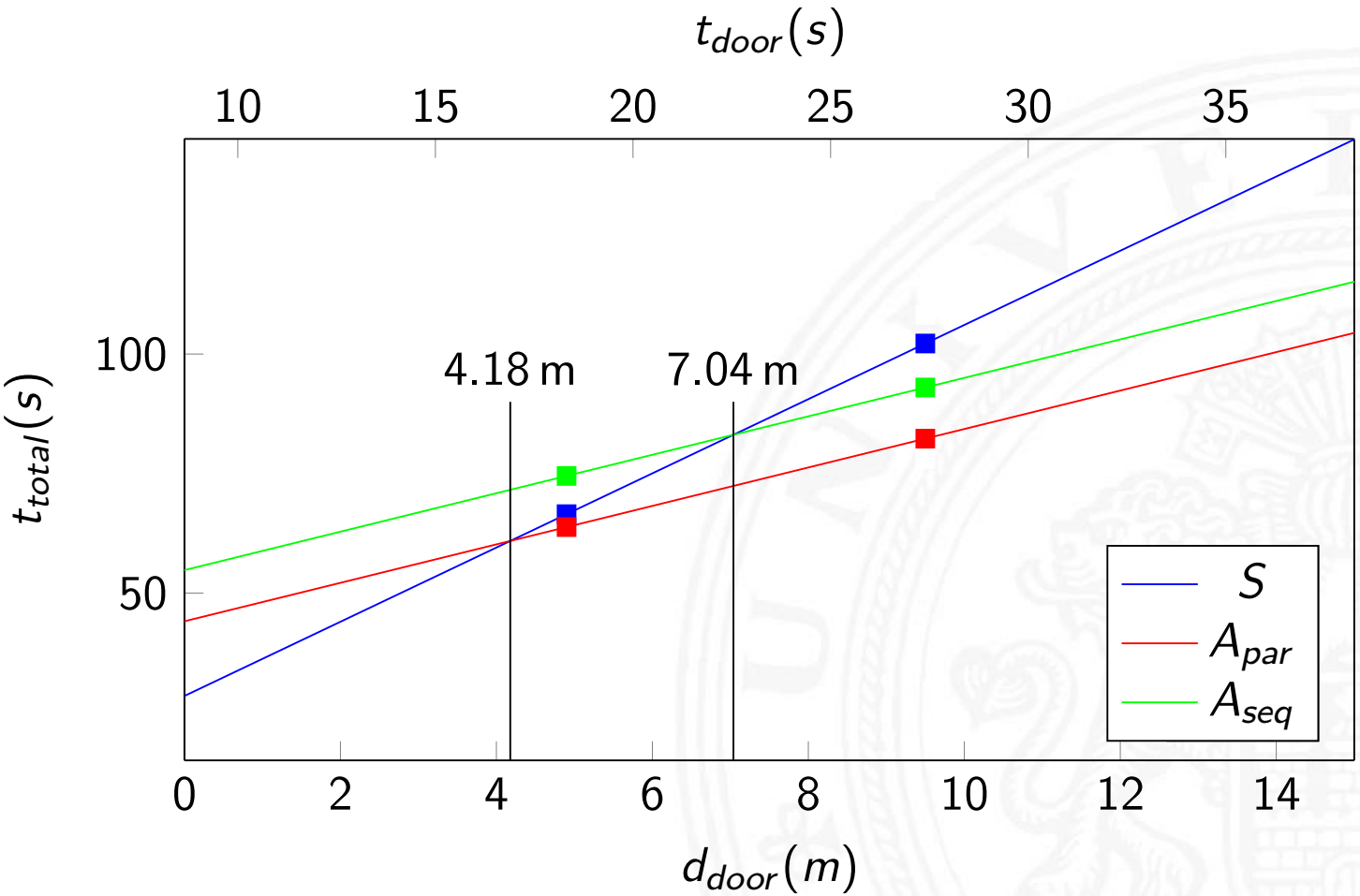
Metrics

- Shortest plan
  - by step count
  - sequential execution duration
  - parallel execution duration

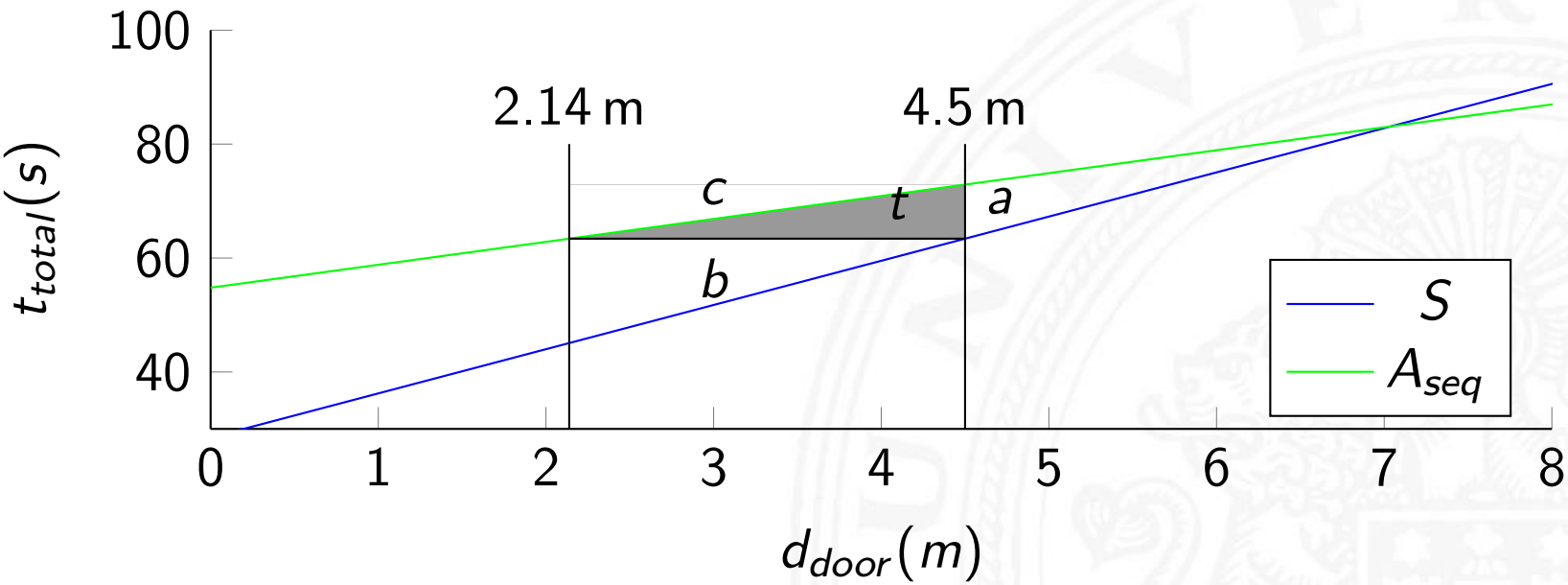
Attend Table



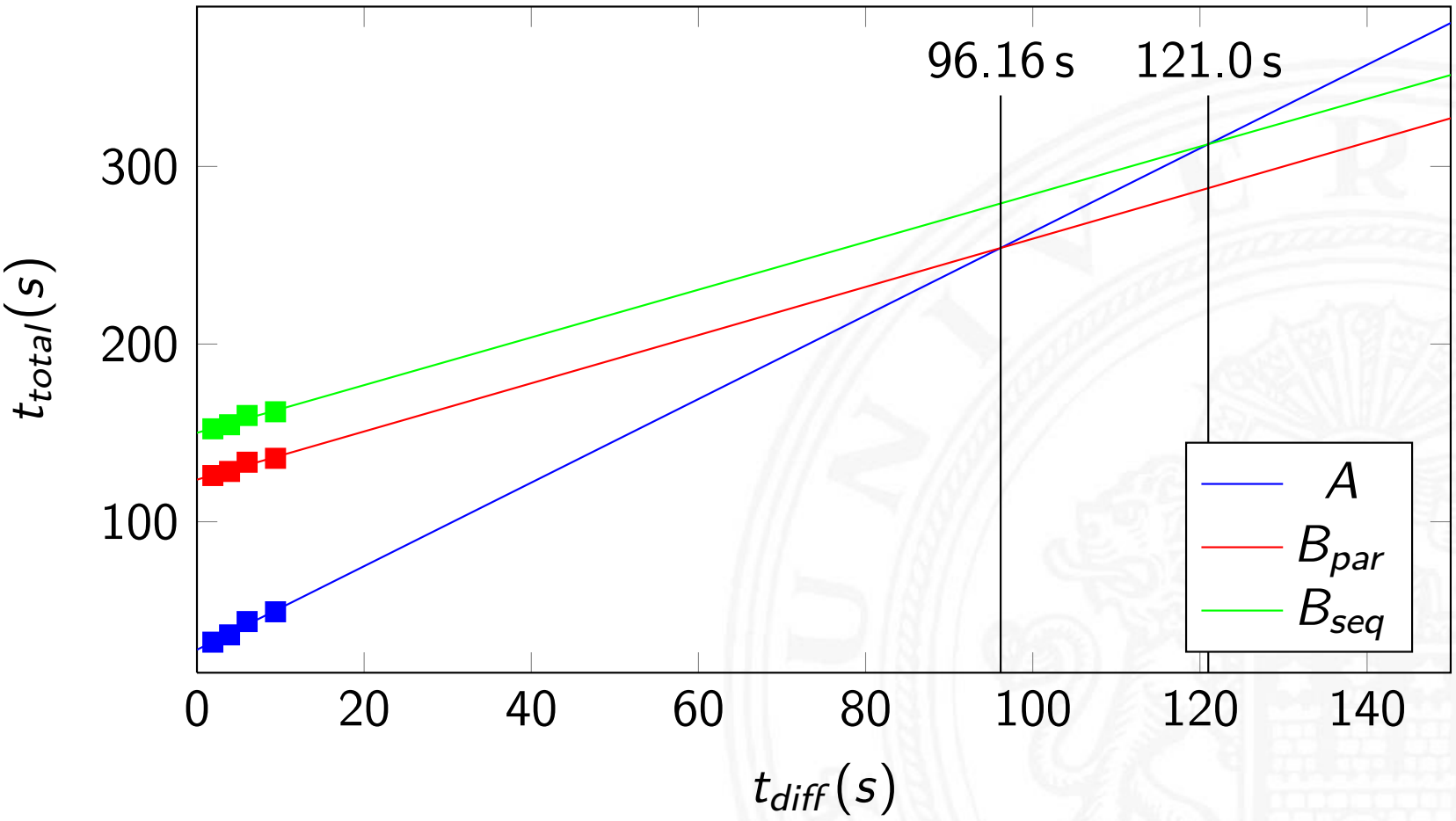
Door


$t_{door}(s)$
10
15
20
25
30
35
100
50
$t_{total}(s)$
4.18 m
7.04 m
S
A_{par}
A_{seq}
0
2
4
6
8
10
12
14
$d_{door}(m)$

Door cont.



Pepper Mill


96.16 s
121.0 s
300
200
100
$t_{total}(s)$
0
20
40
60
80
100
120
140
$t_{diff}(s)$
A
B_{par}
B_{seq}
titel

Conclusion

Conclusion

- Temporal Experience Extractor
- Plan Evaluator
- Scenarios

- Feasibility
  - temporal values
  - general approach
  - complex tasks
- Spacious environments
  - large storage rooms
  - elderly care

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Outlook

- Usability
  - interfaces
- Temporal improvements
  - deviation
  - deduction
- Additional reasoning
  - path properties
  - uncertainty
  - robustness
  - resource requirements

Thank you!

Questions!?

[1] L. Einig, D. Klimentjew, S. Rockel, L. Zhang, and J. Zhang, "Parallel plan execution and re-planning on a mobile robot using state machines with HTN planning systems," in *ROBIO'13*, pp. 151–157, 2013.