Formal-methods support for runtime adaptation in role-based systems

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Chair

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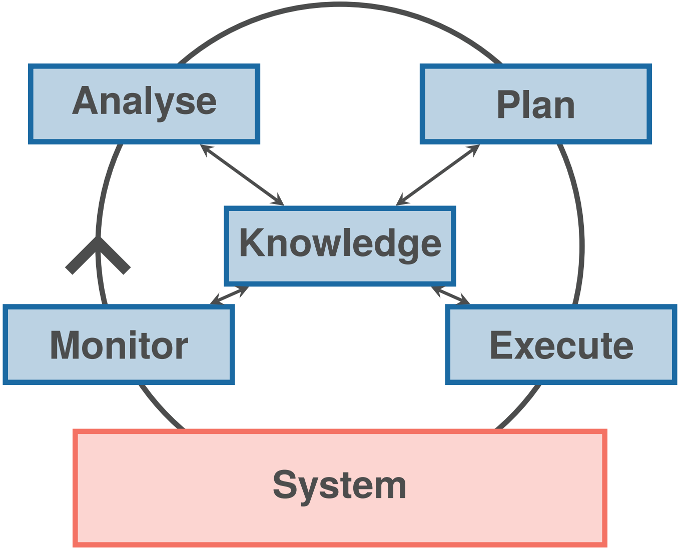
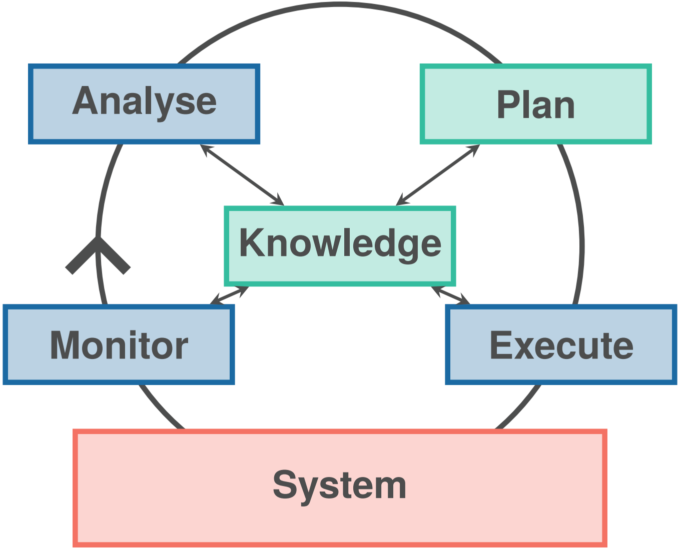
16-11-2020


Analyse
Plan
Knowledge
Monitor
Execute
System


Analyse
Plan
Knowledge
Monitor
Execute
System

Outline

State of the Art

Contributions

- PMC-based Decision Making
- Statistical Analysis of Decider Performance

Experiments

Conclusion

State of the Art

System-verification

Verify system properties at the design stage, like:

- Resilience (Cámara and de Lemos (2012))
- Safety (Güdemann, Ortmeier, and Reif (2006))
- Performance (M. Becker, Luckey, and S. Becker (2013))

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Decision making

Effective decision making by computing expected consequences of decisions

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Decision making

Effective decision making by computing expected consequences of decisions

Main Challenge
Complexity of system representation

Decision making with Formal Methods

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- simulation reduction (Calinescu et al. (2011))
- statistical methods (Iftikhar and Weyns (2014))

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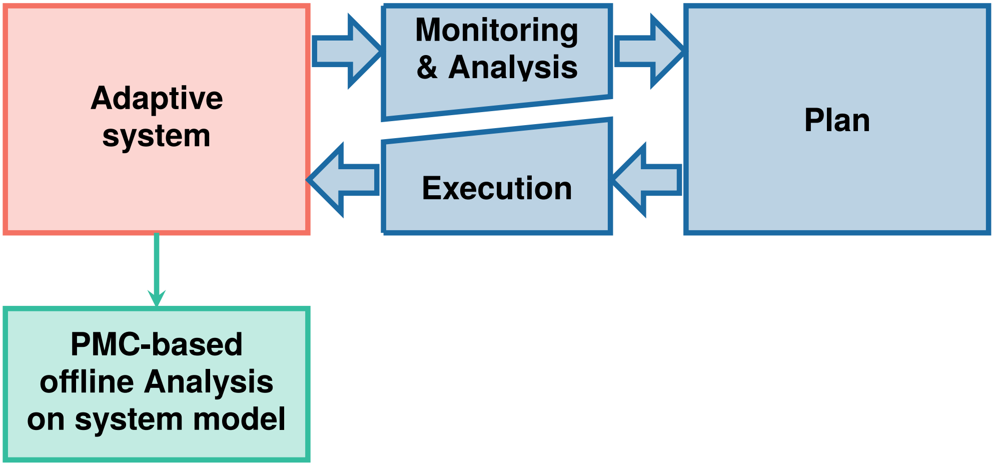
- statistical methods (Iftikhar and Weyns (2014))
- Parametric Model Checking(Filieri, Ghezzi, and Tamburrelli (2011))
- Pre-computation of Scenarios (Saller, Lochau, and Reimund (2013))

Contributions

Fundamental Concept

Fundamental Concept



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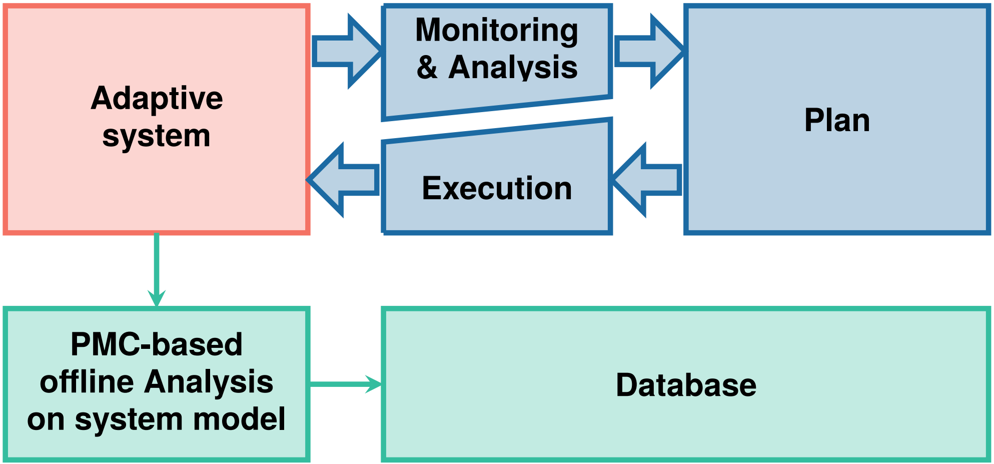

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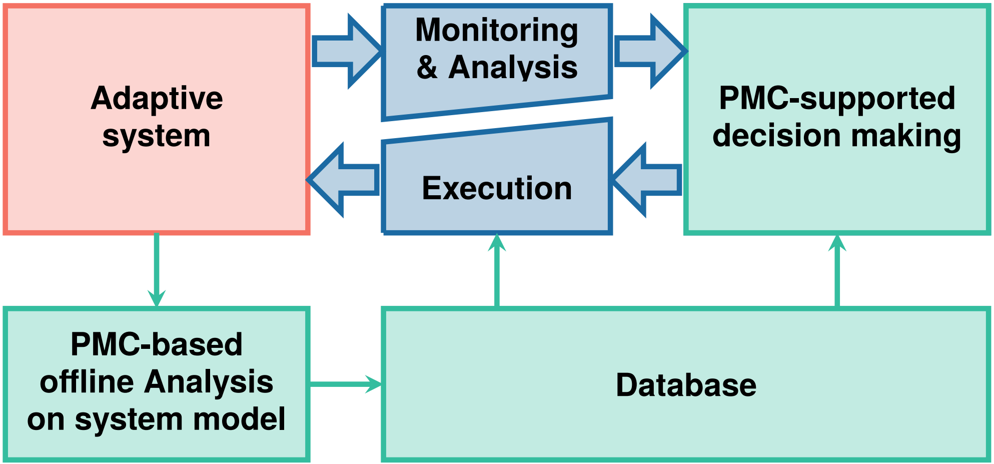
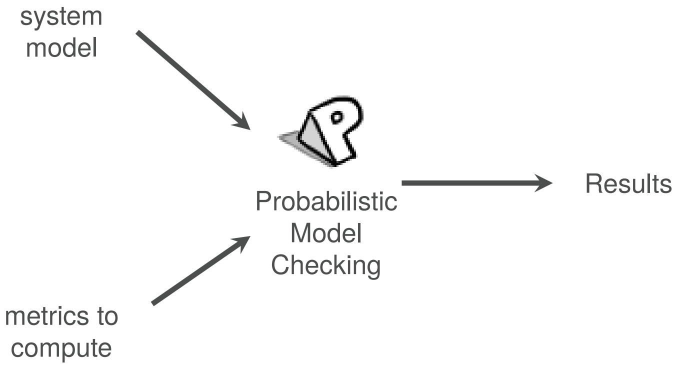


PMC-based Decision Making



Objective of the Decider

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Split the **global objective** into multiple **local metrics**

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Local Metrics

- $Pr(\texttt{P1})$
- $Exp(\texttt{E1})$

⋮

Objective of the Decider

Split the **global objective** into multiple **local metrics**

Global Objective

keep P1 $\geq$ 0.9

minimise E1

⋮

Local Metrics

- $Pr(\texttt{P1})$
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Split the **global objective** into multiple **local metrics**

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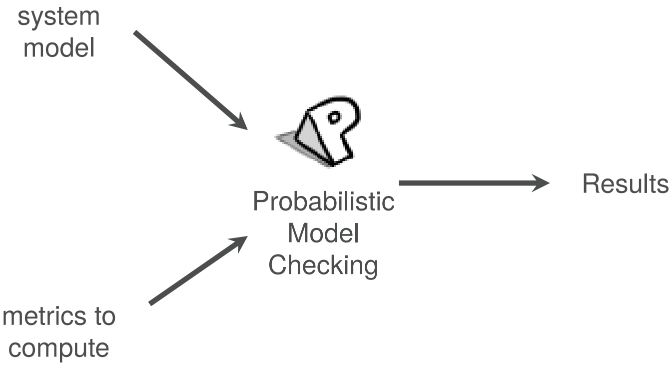
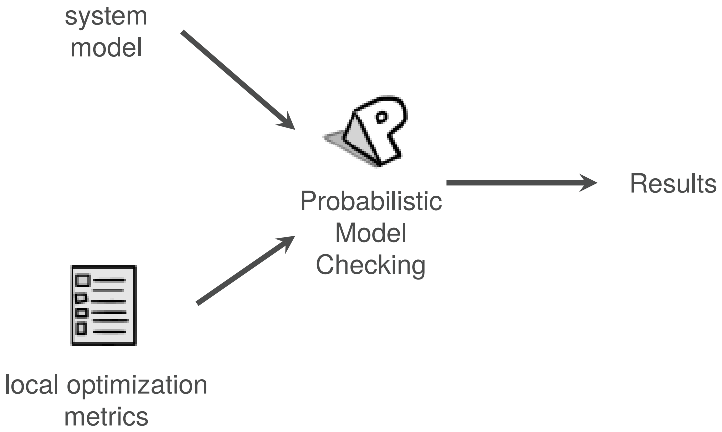
PMC-based Decision Making



PMC-based Decision Making



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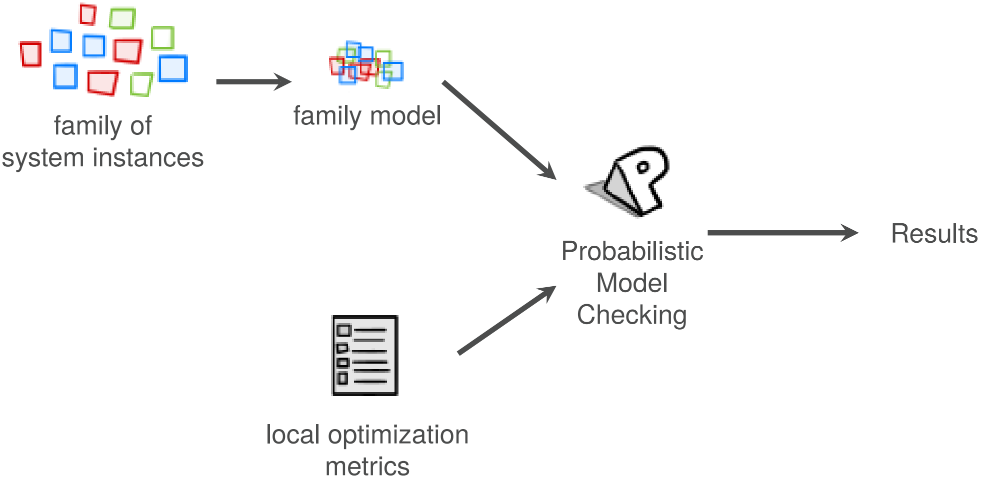
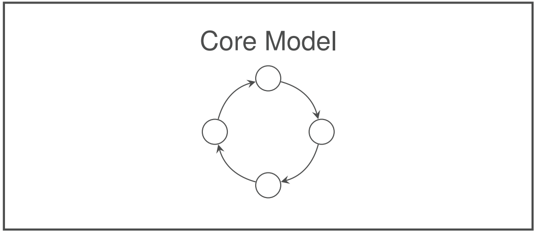


Family Model



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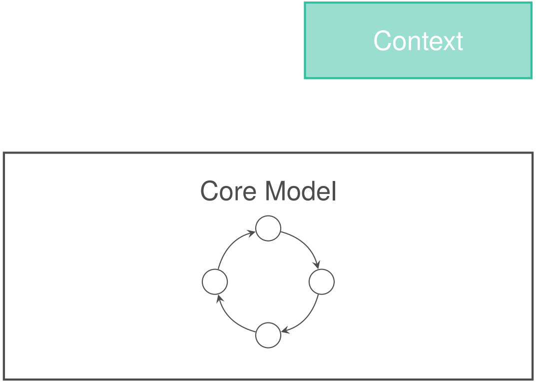

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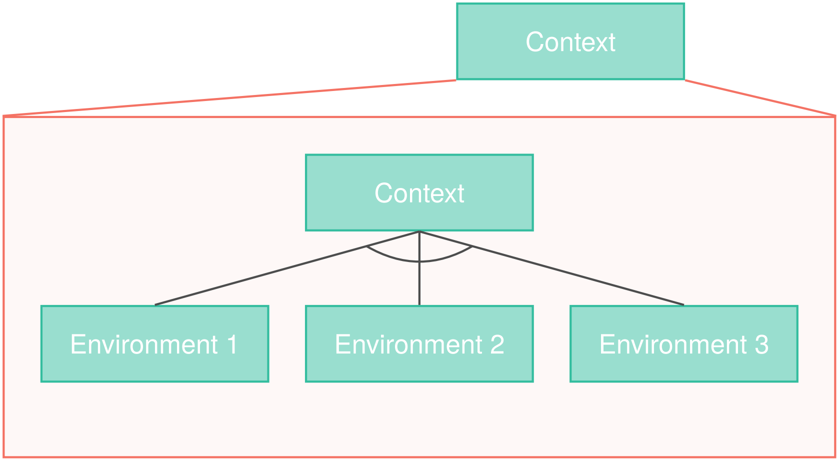

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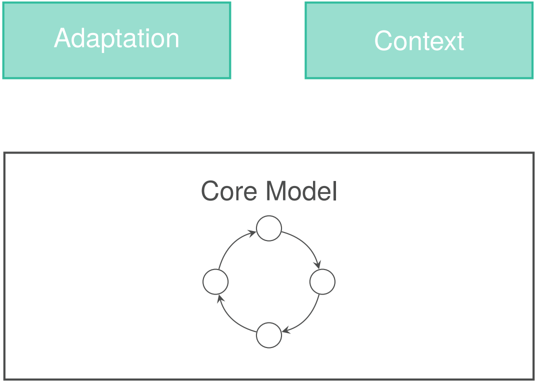

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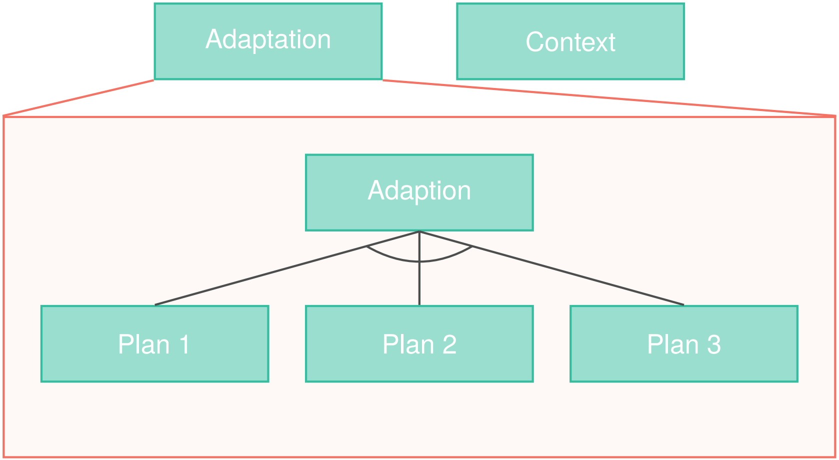

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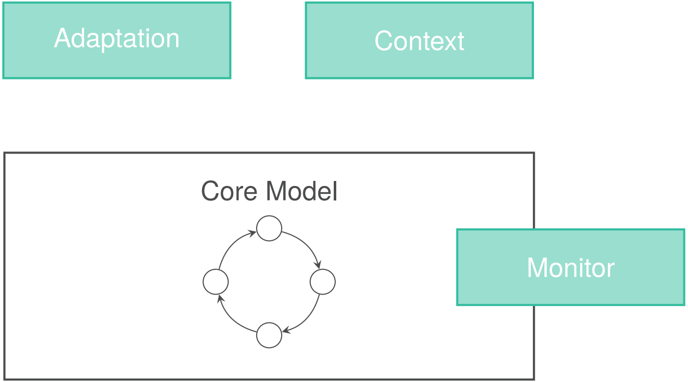

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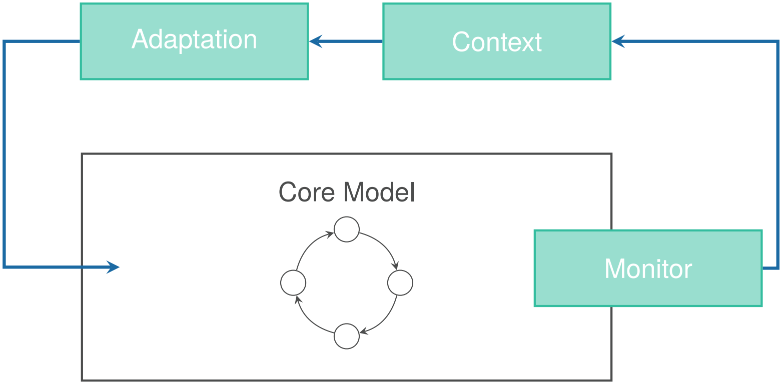

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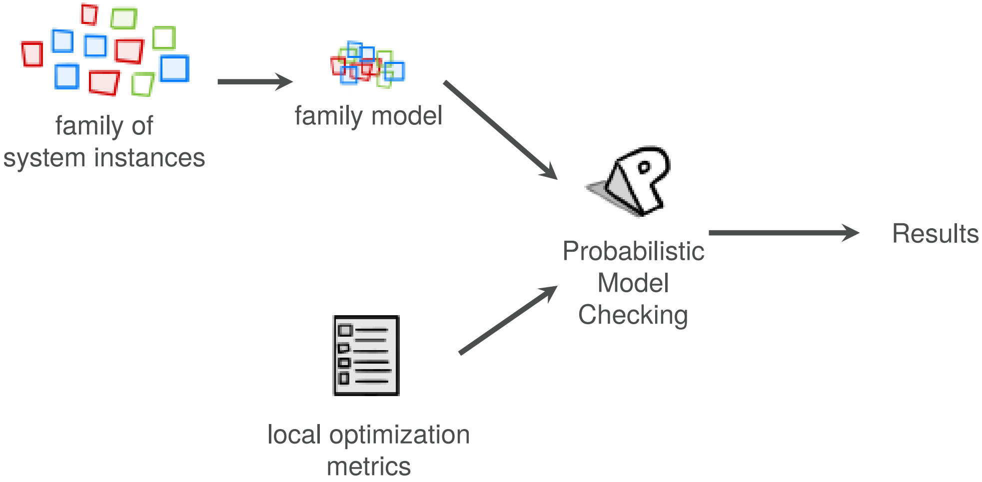

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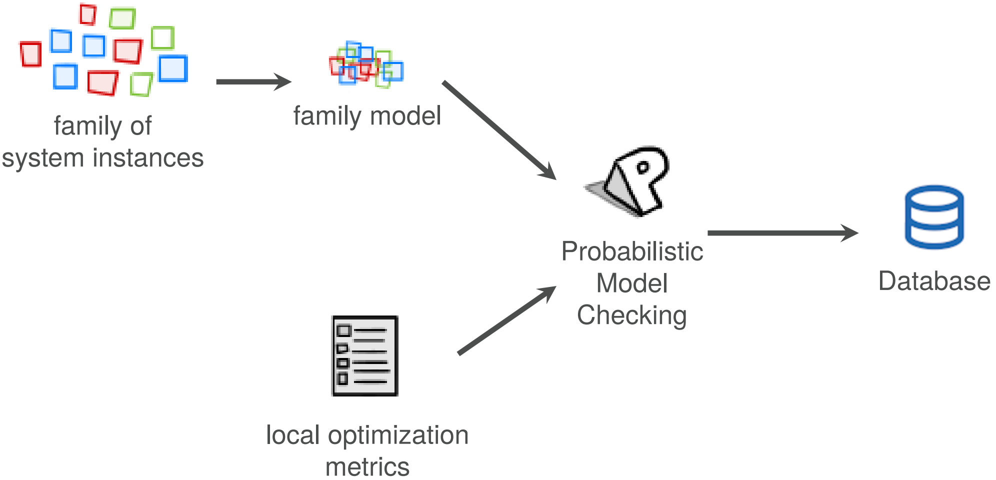
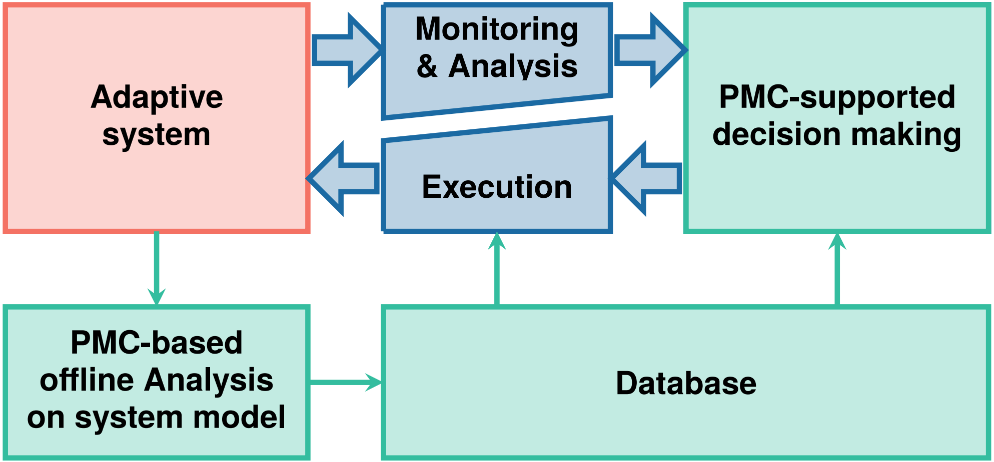


Database

Environment	Plan	Observable Variable 1	Observable Variable 2	P1	E1	...
1	1	0	0	0.7	34.5	...
1	1	0	1	0.64	29.0	...
1	1	1	0	0.61	28.7	...
1	1	1	1	0.57	25.1	...
1	2	0	0	0.9	50.1	...
1	2	0	1	0.95	45.6	...
1	2	1	0	0.81	33.6	...
1	2	1	1	0.89	34.8	...
2	1	0	0	0.3	87.3	...
2	1	0	1	0.4	90.1	...
⋮	⋮	⋮	⋮	⋮	⋮	⋮

Fundamental Concept



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Global Objective

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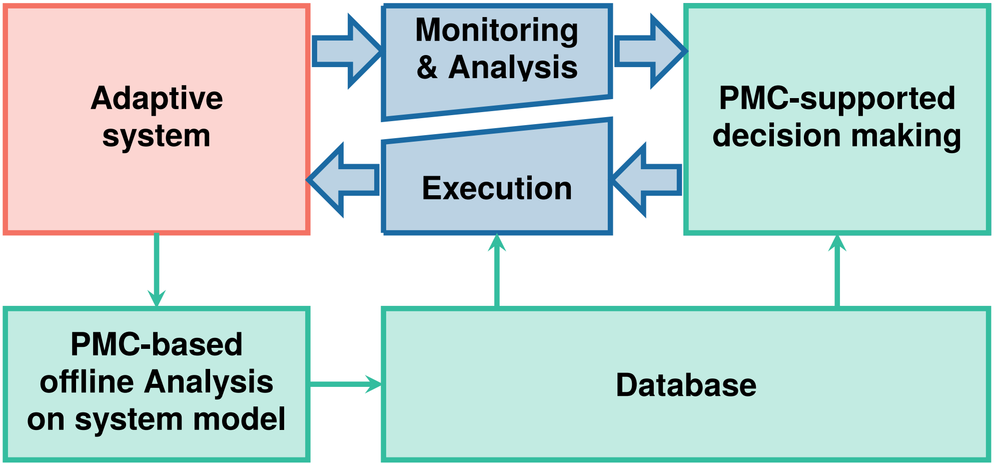
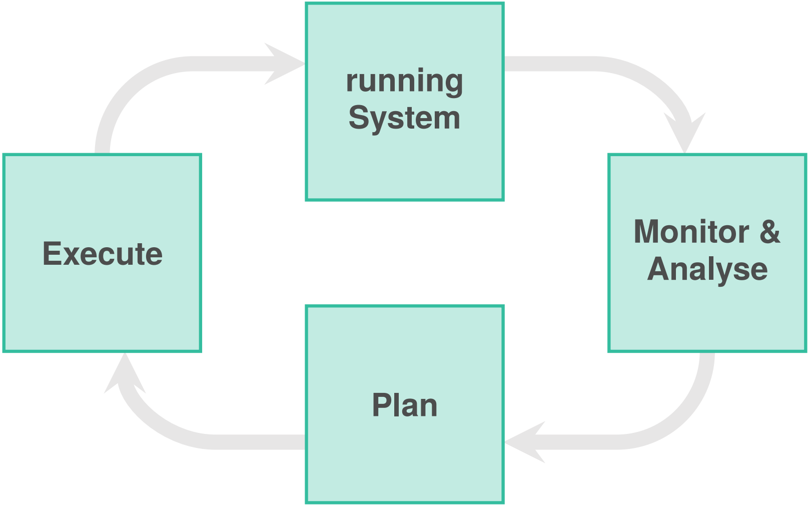


Statistical Analysis of Decider Performance



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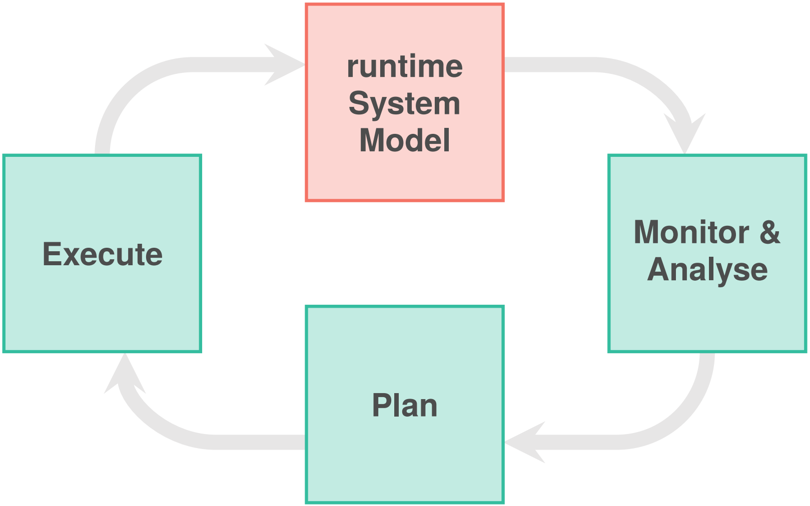

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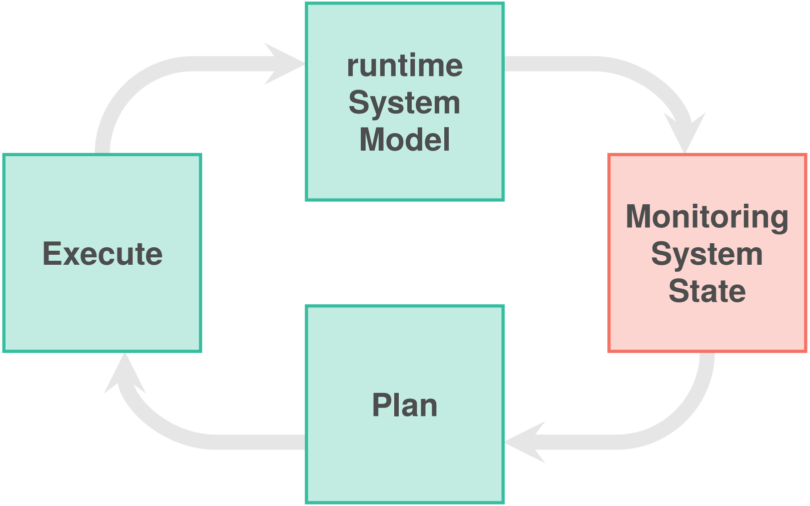

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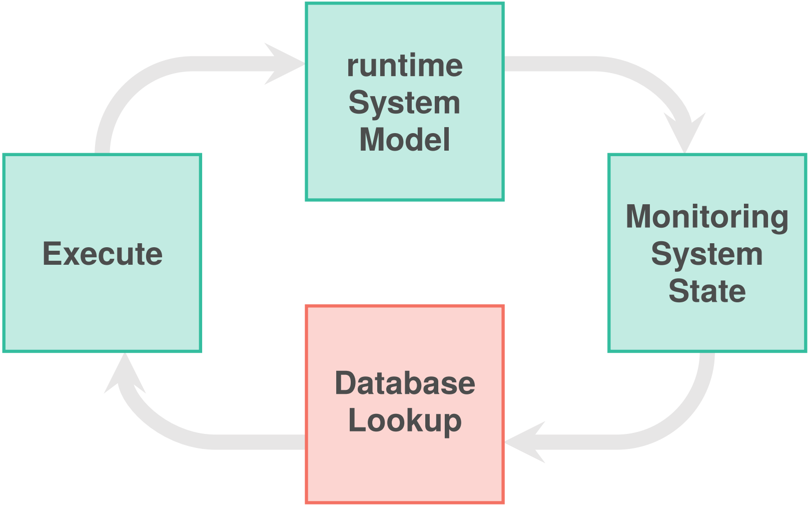

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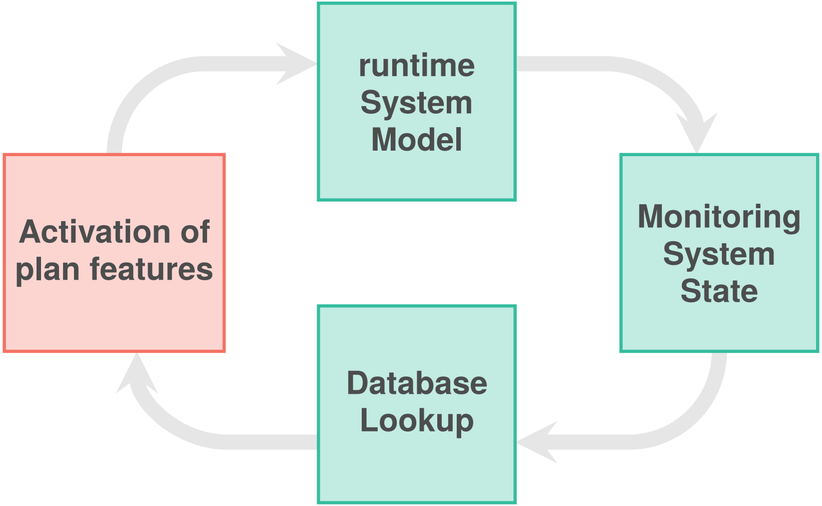

Experiments

Tooling

Implemented using the modelling language ProFeat[1] and the Model Checker Prism[2].

[1] Chrszon et al. (2018)
[2] Kwiatkowska, Norman, and Parker (2011)

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Successful self-adaptation on Prism case-study models:

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Tooling

Implemented using the modelling language ProFeat[1] and the Model Checker Prism[2].

Successful self-adaptation on Prism case-study models:

- Real Time Voltage Scaling (Kwiatkowska, Norman, and Parker (2005))
- Human in the Loop UAV Mission Planning (Feng et al. (2015))
- Network Virus Infection (Kwiatkowska, Norman, Parker, and Vigliotti (2009))

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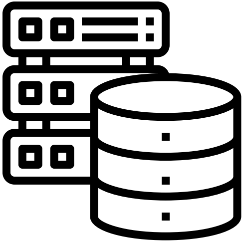
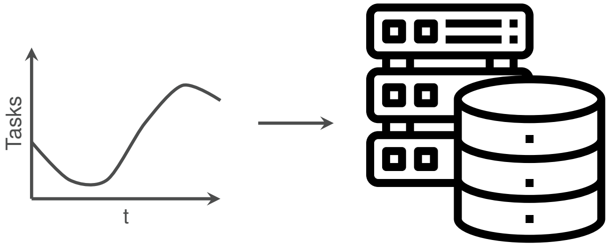
Experiment Scenario



Adaptive DBMS

Experiment Scenario



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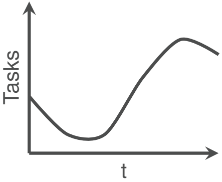
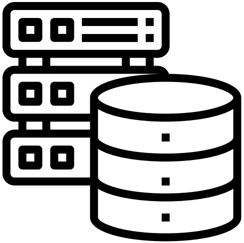




Adaptive DBMS

Adaptation

- Cores
- Frequency
- Hyper-Threading

Global Objective

Global Objective

Compute
all tasks

Global Objective

Compute all tasks

reduce Energy Costs

Global Objective

Global Objective

`Schedule:` $Pr(\text{all tasks computed})$

Global Objective

$\texttt{Schedule:} Pr(\text{all tasks computed})$ $\texttt{Costs:} Exp(\text{Costs})$

Global Objective

Compute all tasks ⟷ **Trade-off** ⟷ **reduce Energy Costs**

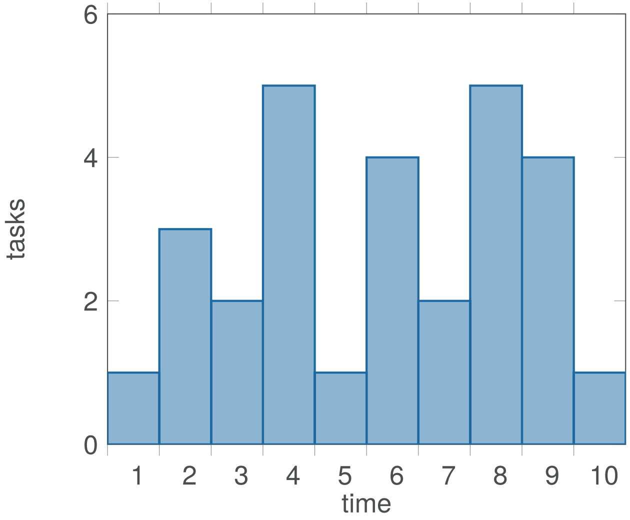
$\texttt{Schedule:} Pr(\text{all tasks computed})$

$\texttt{Costs:} Exp(\text{Costs})$

$\texttt{Budget:} Pr(\text{all tasks computed} \wedge \text{costs in budget})$

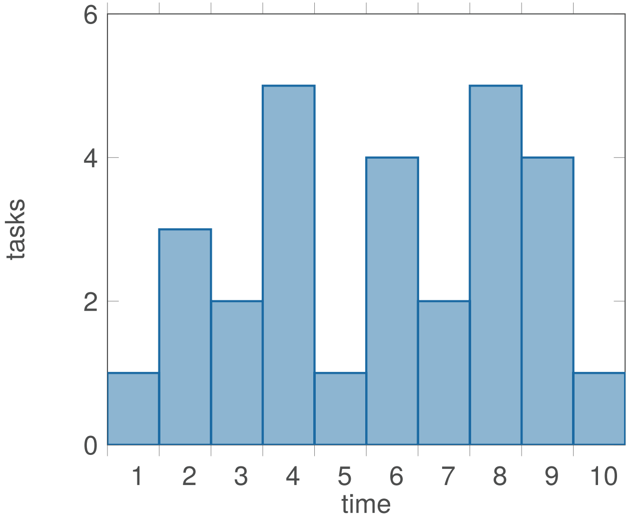
Experimental Setup

- Environment



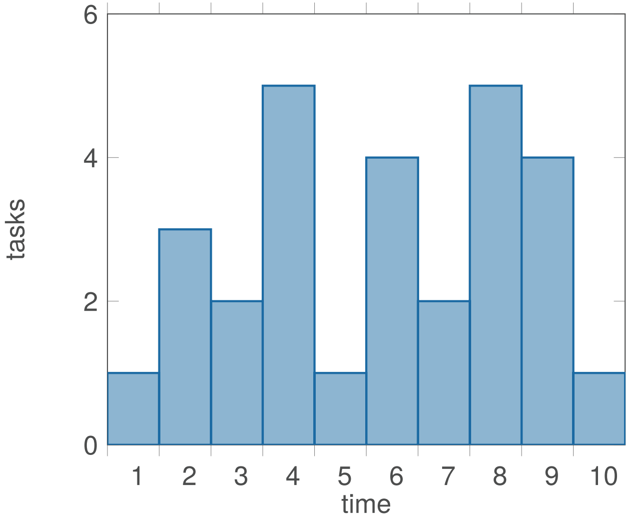
Experimental Setup

- Environment
- lookahead



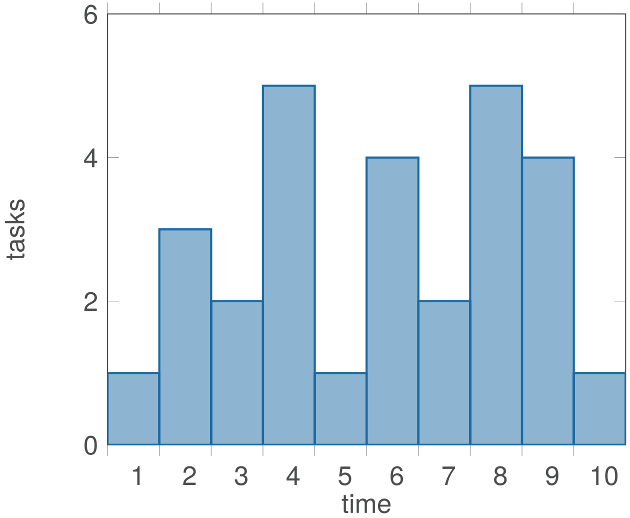
Experimental Setup

- Environment
- lookahead
- time between decisions



Experimental Setup

- Environment
- lookahead
- time between decisions
- noise-factor



Experimental Setup

- Environment
- lookahead
- time between decisions
- noise-factor
- Strategy

Experimental Setup

- Environment
- lookahead
- time between decisions
- noise-factor
- Strategy
  - `Max-Schedule`

`Max-Schedule:`

maximise `Schedule`

miminise `Costs`

Experimental Setup

- Environment
- lookahead
- time between decisions
- noise-factor
- Strategy
  - `Max-Schedule`
  - `Filter-Schedule`

`Filter-Schedule:`

keep `Schedule` $\geq$ 0.9

miminise `Costs`

Experimental Setup

RoSI

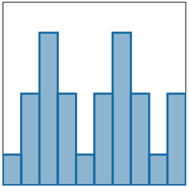
- Environment
- lookahead
- time between decisions
- noise-factor
- Strategy
  - `Max-Schedule`
  - `Filter-Schedule`
  - `Max-Budget`

`Max-Budget:`

maximise `Budget`

miminise `Costs`

Effect of Lookahead

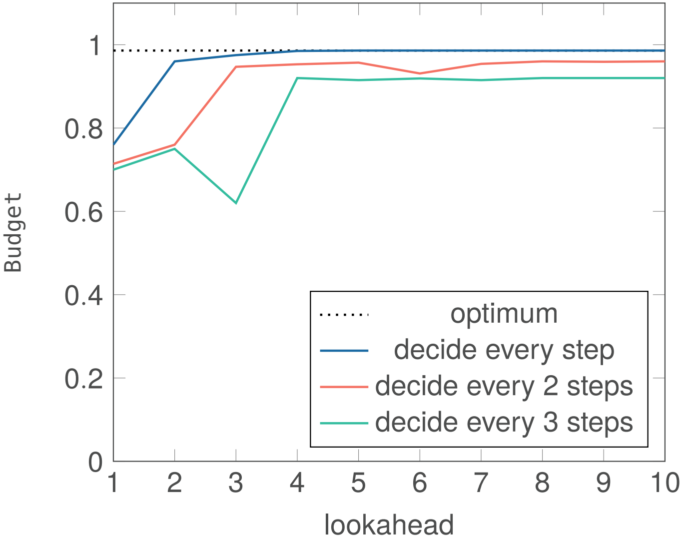


Lookahead: ∗

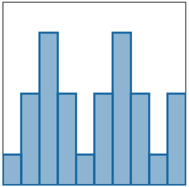
Decisions: ∗

Noise: 0

Strategy: `Max-Budget`



Effect of Noise

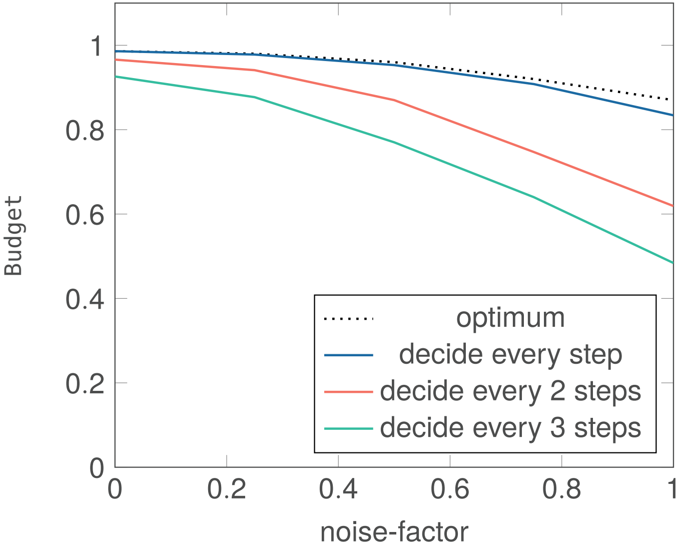


Lookahead: 10

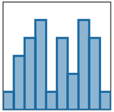
Decisions: ∗

Noise: ∗

Strategy: `Max-Budget`



Strategy Comparison

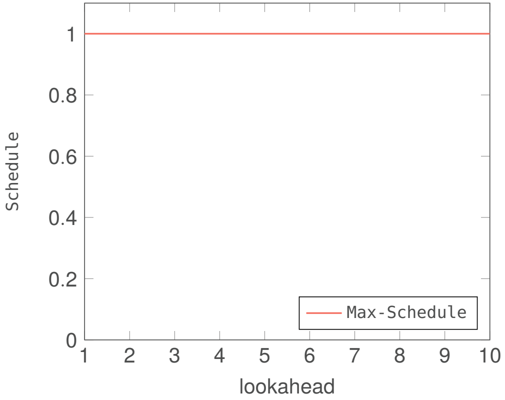


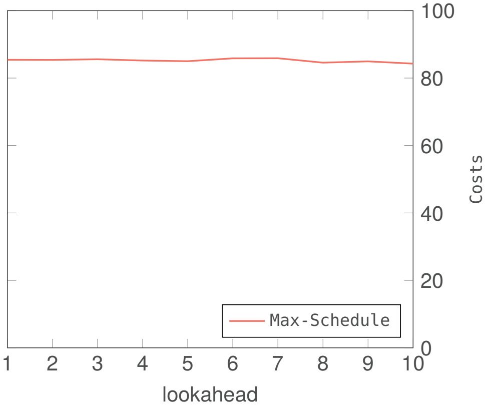
Lookahead: ∗

Decisions: every step

Noise: 0

Strategy: ∗





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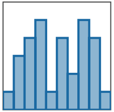
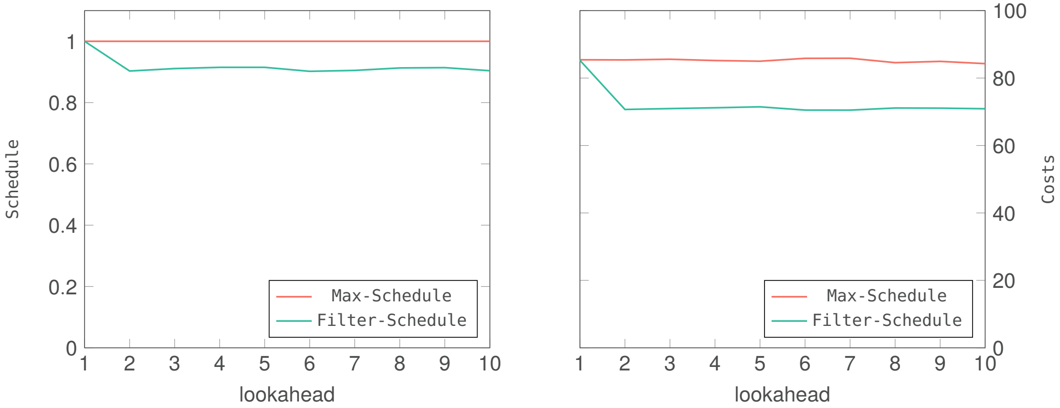


Lookahead: ∗

Decisions: every step

Noise: 0

Strategy: ∗



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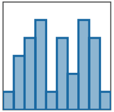
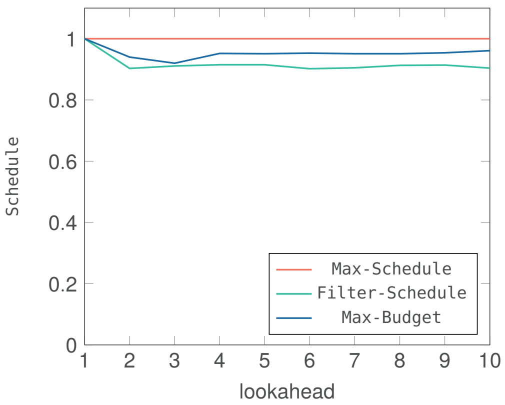


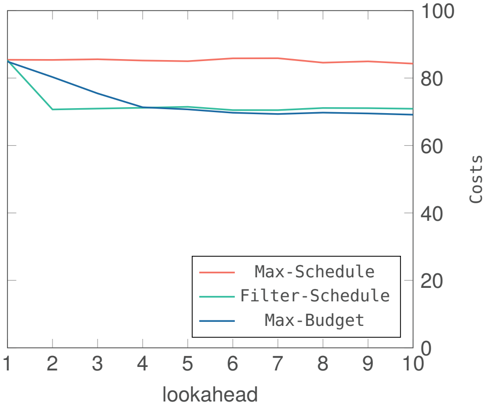
Lookahead: *

Decisions: every step

Noise: 0

Strategy: *





Conclusion

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- Decision making approach using offline PMC

Conclusion

- Decision making approach using offline PMC
- Analysis tool using statistic MC

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Paper in progress

Conclusion

- Decision making approach using offline PMC
- Analysis tool using statistic MC

Paper in progress

Further analysis:

- effects of environmental changes

Conclusion

- Decision making approach using offline PMC
- Analysis tool using statistic MC

Paper in progress

Further analysis:

- effects of environmental changes
- separating global objective in local metrics

Related Work I

- Becker, Matthias, Markus Luckey, and Steffen Becker (2013). "Performance Analysis of Self-Adaptive Systems for Requirements Validation at Design-Time". In: *Proceedings of the 9th International ACM Sigsoft Conference on Quality of Software Architectures*. QoSA '13. Vancouver, British Columbia, Canada: Association for Computing Machinery, pp. 43–52. ISBN: 9781450321266. DOI: 10.1145/2465478.2465489. URL: https://doi.org/10.1145/2465478.2465489.
- Calinescu, R. et al. (2011). "Dynamic QoS Management and Optimization in Service-Based Systems". In: *IEEE Transactions on Software Engineering* 37.3, pp. 387–409. DOI: 10.1109/TSE.2010.92.
- Cámara, J. and R. de Lemos (2012). "Evaluation of resilience in self-adaptive systems using probabilistic model-checking". In: *2012 7th International Symposium on Software Engineering for Adaptive and Self-Managing Systems (SEAMS)*, pp. 53–62. DOI: 10.1109/SEAMS.2012.6224391.
- Chrszon, Philipp et al. (2018). *ProFeat: feature-oriented engineering for family-based probabilistic model checking*. DOI: 10.1007/s00165-017-0432-4.

Related Work II

- Feng, Lu et al. (2015). "Controller Synthesis for Autonomous Systems Interacting with Human Operators". In: *Proceedings of the ACM/IEEE Sixth International Conference on Cyber-Physical Systems*. ICCPS '15. Seattle, Washington: Association for Computing Machinery, pp. 70–79. ISBN: 9781450334556. DOI: 10.1145/2735960.2735973. URL: https://doi.org/10.1145/2735960.2735973.
- Filieri, Antonio, Carlo Ghezzi, and Giordano Tamburrelli (2011). "Run-Time Efficient Probabilistic Model Checking". In: *Proceedings of the 33rd International Conference on Software Engineering*. ICSE '11. Waikiki, Honolulu, HI, USA: Association for Computing Machinery, pp. 341–350. ISBN: 9781450304450. DOI: 10.1145/1985793.1985840. URL: https://doi.org/10.1145/1985793.1985840.
- Güdemann, M., F. Ortmeier, and W. Reif (2006). "Safety and Dependability Analysis of Self-Adaptive Systems". In: *Second International Symposium on Leveraging Applications of Formal Methods, Verification and Validation (isola 2006)*, pp. 177–184. DOI: 10.1109/ISoLA.2006.38.

Related Work III

- Iftikhar, M. Usman and Danny Weyns (2014). "ActivFORMS: Active Formal Models for Self-Adaptation". In: *Proceedings of the 9th International Symposium on Software Engineering for Adaptive and Self-Managing Systems*. SEAMS 2014. Hyderabad, India: Association for Computing Machinery, pp. 125–134. ISBN: 9781450328647. DOI: 10.1145/2593929.2593944. URL: https://doi.org/10.1145/2593929.2593944.
- Kwiatkowska, M., G. Norman, and D. Parker (2005). "Probabilistic Model Checking and Power-Aware Computing". In: *Proc. 7th International Workshop on Performability Modeling of Computer and Communication Systems (PMCCS'05)*, pp. 6–9.
- – (2011). "PRISM 4.0: Verification of Probabilistic Real-time Systems". In: *Proc. 23rd International Conference on Computer Aided Verification (CAV'11)*. Ed. by G. Gopalakrishnan and S. Qadeer. Vol. 6806. LNCS. Springer, pp. 585–591.
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Related Work IV

Saller, Karsten, Malte Lochau, and Ingo Reimund (2013). "Context-Aware DSPLs: Model-Based Runtime Adaptation for Resource-Constrained Systems". In: *Proceedings of the 17th International Software Product Line Conference Co-Located Workshops*. SPLC '13 Workshops. Tokyo, Japan: Association for Computing Machinery, pp. 106–113. ISBN: 9781450323253. DOI: 10.1145/2499777.2500716. URL: https://doi.org/10.1145/2499777.2500716.