TECHNISCHE UNIVERSITÄT WIEN
Vienna | Austria

Institut für Computertechnik
Institute of Computer Technology

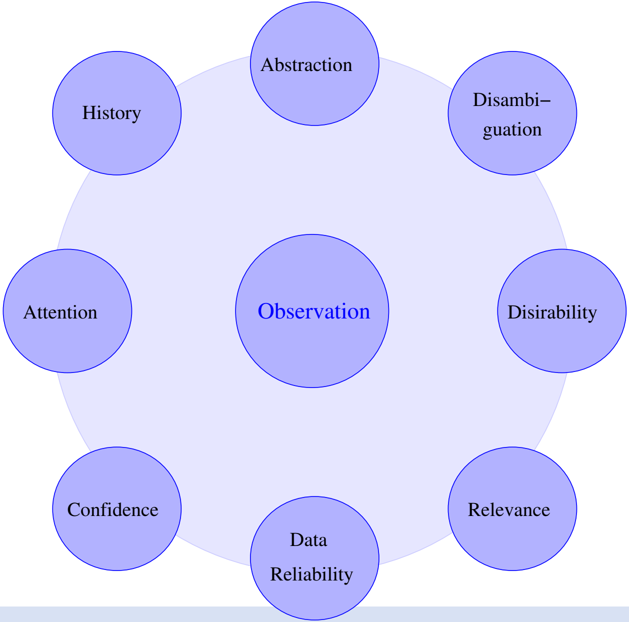
Context Aware Monitoring

Axel Jantsch

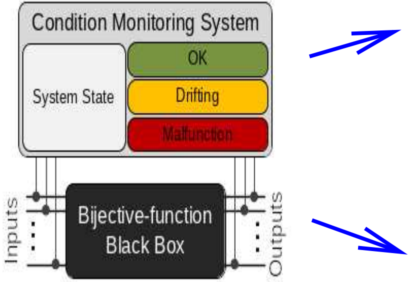
November 25, 2021

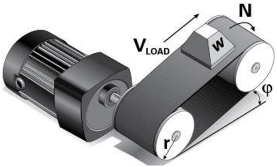
Outline

Observation Circle



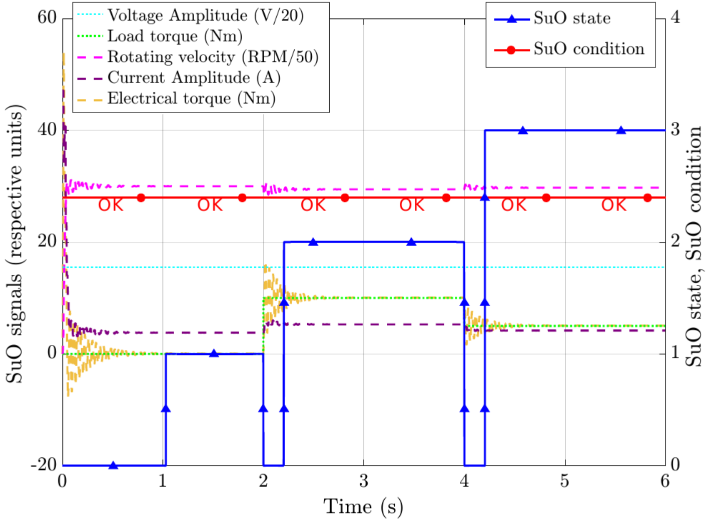
Industrial Motor

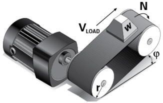




M. Götzinger, N. TaheriNejad, H. A. Kholerdi, and A. Jantsch. “On the design of context-aware health monitoring without a priori knowledge; an AC-Motor case-study”. In: *2017 IEEE 30th Canadian Conference on Electrical and Computer Engineering (CCECE)*. Apr. 2017, pages 1–5

Industrial Motor





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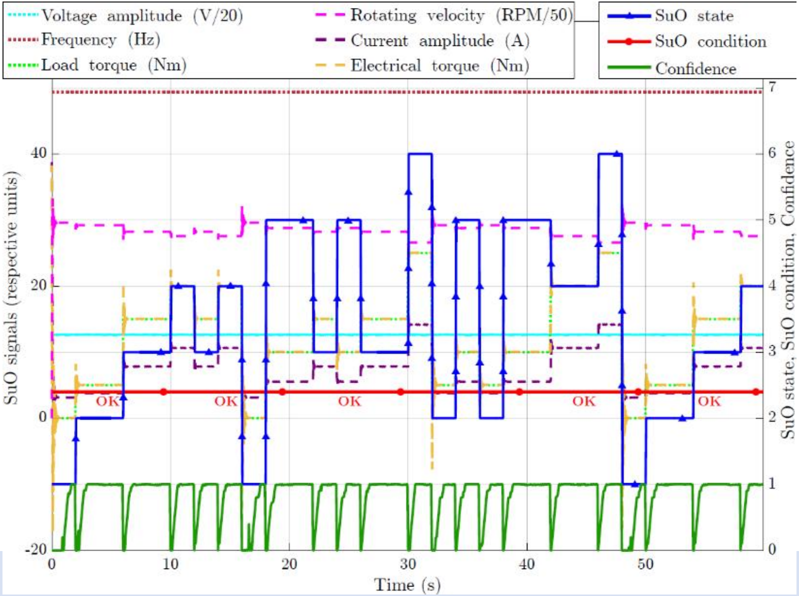

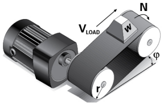

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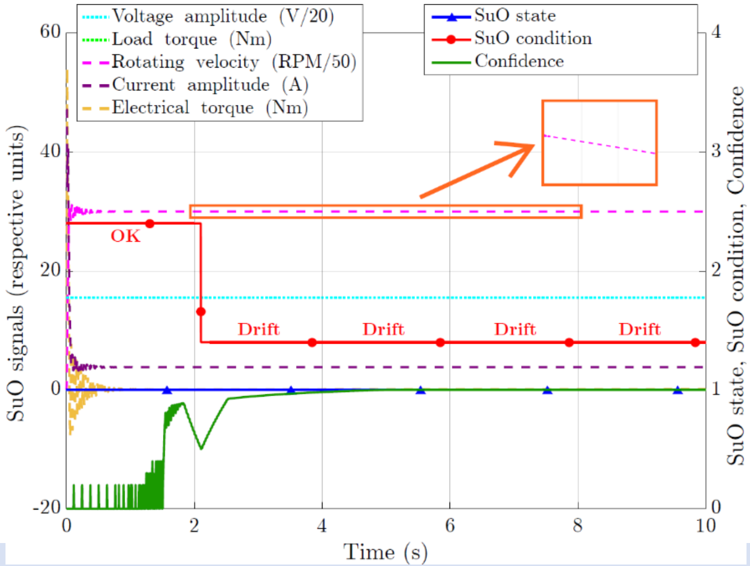

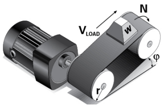

Hydraulic Pipe System

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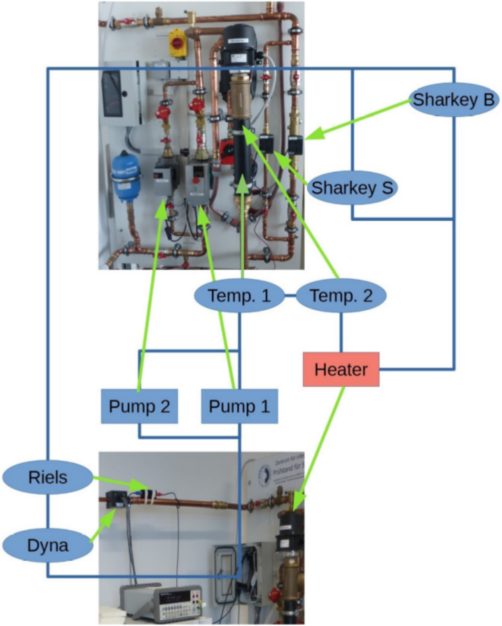
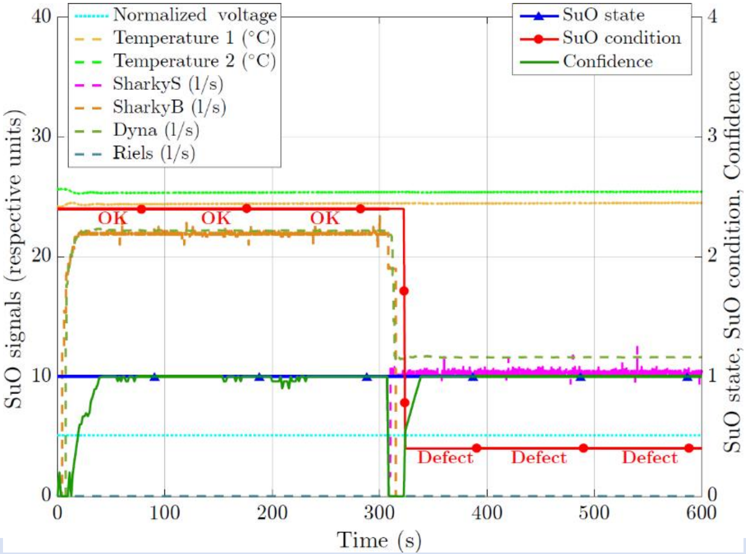
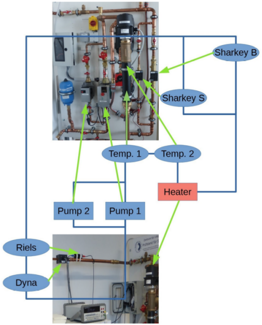


Maximilian Götzinger et al. "Applicability of Context-Aware Health Monitoring to Hydraulic Circuits". In: *The 44th Annual Conference of the IEEE Industrial Electronics Society*. 2018

Hydraulic Pipe System





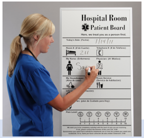
Early Warning Score

Early Warning Score

Score	3	2	1	0	1	2	3
Heart rate[1]	<40	40–51	51–60	60–100	100–110	110–129	>129
Systolic BP[2]	<70	70–81	81–101	101–149	149–169	169–179	>179
Breath rate[3]		<9		9–14	14–20	20–29	>29
SPO_2 (%)	<85	85–90	90–95	>95			
Body temp.[4]	<28	28–32	32–35	35–38		38–39.5	>39.5

[1]beats per minute, [2]mmHg, [3]breaths per minute, [4] °C





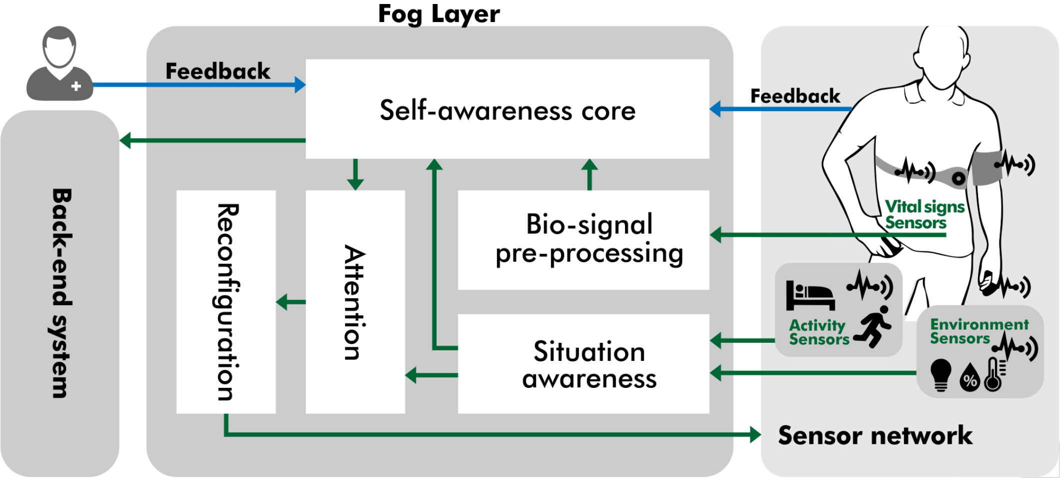
EWS Improvement

- Data reliability:
  - Values in reasonable scope
  - Changes in reasonable scope
  - Consistency between sensors
- Situation awareness
- Power efficiency

Arman Anzanpour et al. "Self-Awareness in Remote Health Monitoring Systems using Wearable Electronics". In: *Proceedings of Design and Test Europe Conference (DATE)*. Lausanne, Switzerland, Mar. 2017

Maximilian Götzinger et al. "Confidence-Enhanced Early Warning Score Based on Fuzzy Logic". In: *Mobile Networks and Applications* (2019)

Enhanced Early Warning Score



Enhanced Early Warning Score - Data Reliability

1. Check on the reliability of sensed values
2. Check on the reliability of value changes
3. Check on consistency between sensor data

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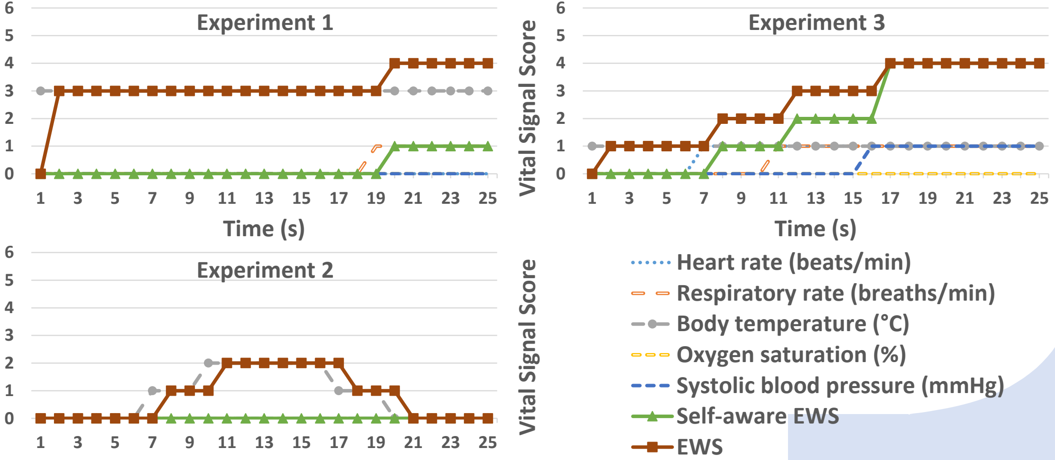

Enhanced Early Warning Score - Situation Awareness

1. Consider the activity mode of person
2. Consider time of day
3. Consider location

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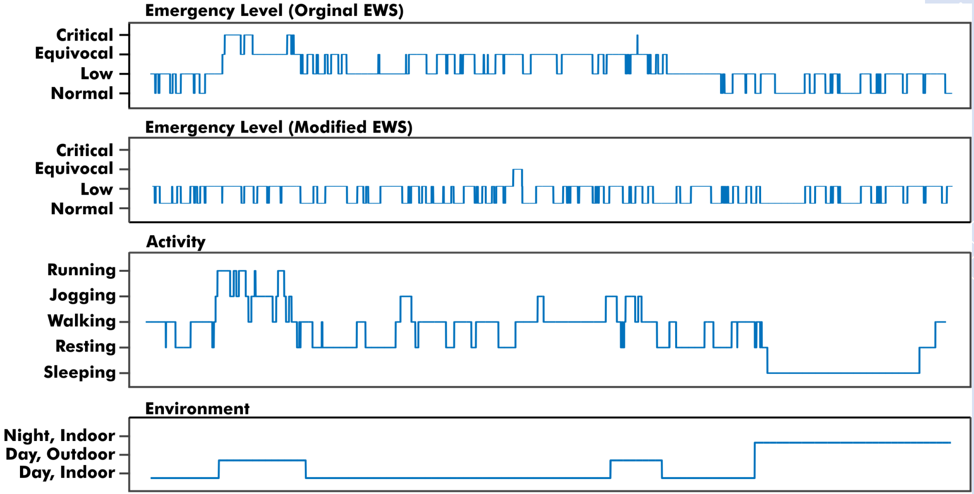


❶ Prioritize different situations

Enhanced Early Warning Score - Power Efficiency

1. Prioritize different situations
2. Distinguish different modes of urgency

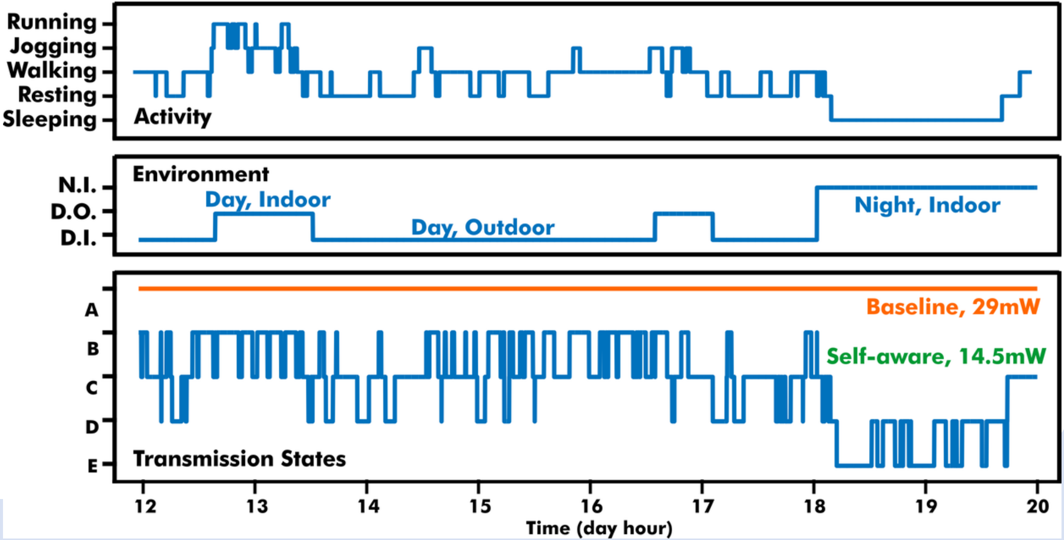
Emergency Level:	Score:0 Normal				Score:1-3 Low				Score:4-6 Medium				Score>6 High			
	Indoor		Outdoor		Indoor		Outdoor		Indoor		Outdoor		Indoor		Outdoor	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Sleeping	E	E	E	E	C	D	D	D	B	C	C	C	A	A	B	B
Resting	D	D	D	D	C	C	C	C	B	B	B	B	A	A	B	B
Walking	C	C	C	C	B	C	C	C	B	B	B	B	A	A	A	B
Jogging	C	C	C	C	B	B	B	C	B	B	B	B	A	A	A	B
Running	C	C	C	C	B	B	B	B	B	B	B	B	A	A	A	A

Enhanced Early Warning Score - Power Efficiency

1. Prioritize different situations
2. Distinguish different modes of urgency
3. Define sensing activity for each mode

State	Respiration Rate Activity	Blood Pressure	Heart Rate, SpO2, and Body Temp.	Transmission Power Consumption
A	Continuous	Every hour in day Disabled in night	Every sec.	29 mW
B	2 min continuous 8 min OFF	Every hour in day Disabled in night	Every sec.	26.8 mW
C	2 min continuous 3 min OFF	Every 3 hours in day Disabled in night	Every min.	12.5 mW
D	2 min continuous 8 min OFF	Every 3 hours in day Disabled in night	Every min.	7 mW
E	2 min continuous 18 min OFF	Disabled	Every min.	4.3 mW

Over a day half the energy can be saved.



Enhanced Early Warning Score Summary

- Considering data reliability improves quality of observation;
- Considering sitation improves quality of observation;
- Collecting needed data only improves efficiency.

Smart Grids

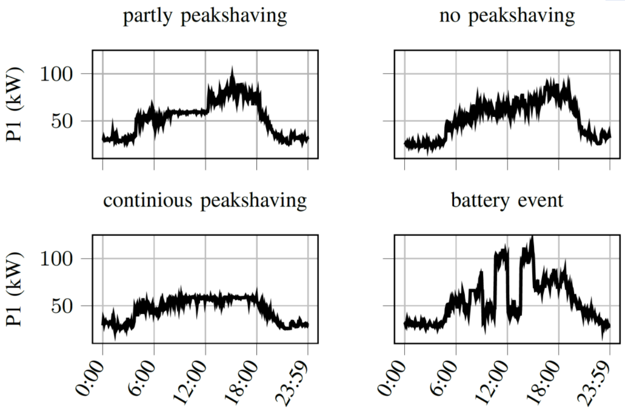
Smart Grid Monitoring

- Decentralized energy consumers/producers
- Renewable energy systems
- E-mobility
- New control and protection concepts
- Intelligent event detection and root cause analysis
- Huge amount of heterogenous data
- Machine Learning concepts are resource-intensive

Daniel Hauer, Maximilian Götzinger, Axel Jantsch, and Florian Kintzler. “Context Aware Monitoring for Smart Grids”. In: *Proceedings of the International Symposium on Industrial Electronics (ISIE)*. Kyoto, Japan, June 2021

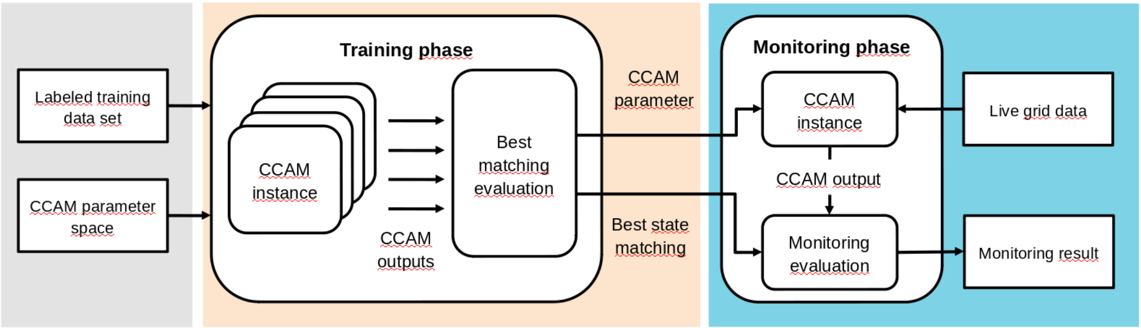
Case Study: Battery-Supported Substation

- Available Historical Grid Data:
  - Testbed Vienna, Austria
  - 12 distribution substations
- Battery-supported Substation
  - Battery tries to limit load to 60 kW
  - Charging during night
- Day-profile Clustering
  - Analysis based on statistical, spectral and temporal features
  - Dominant behavior is "partly peakshaving"



Day profile	Partly peak-shaving	No peak-shaving	Full peak-shaving	Maintenance event
Occurrence	68%	17%	14%	1%

Smart Grids Monitoring Methodology



Configuration

- Use case definition
- Labeled data set
- Parameter space

Training

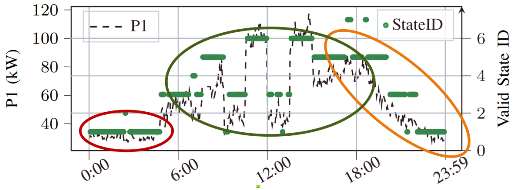
- Multiple CCAM instances
- Best matching evaluation
- High computational effort

Monitoring

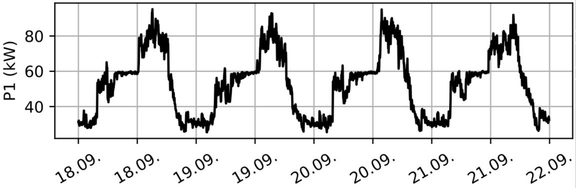
- Single CCAM instance
- Live Monitoring results
- Low computational effort

Training

- Labeled training data for the identified categories
- CCAM parameter set with highest overall confidence



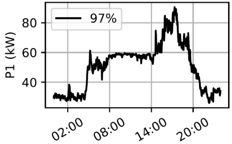
State identification and pattern assignment

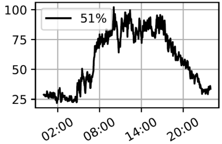


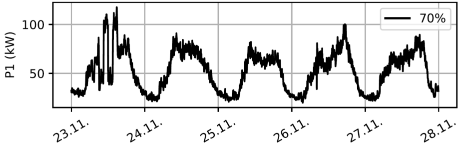
4 days of the training set for partial peak-shaving

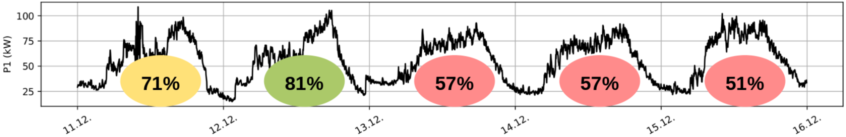
Monitoring

- Live data stream: Only single CCAM instance
- Result:
  - Analysis of 14 weeks starting September 2018
  - Confidence (with 70% threshold) indicates whether system operates as expected







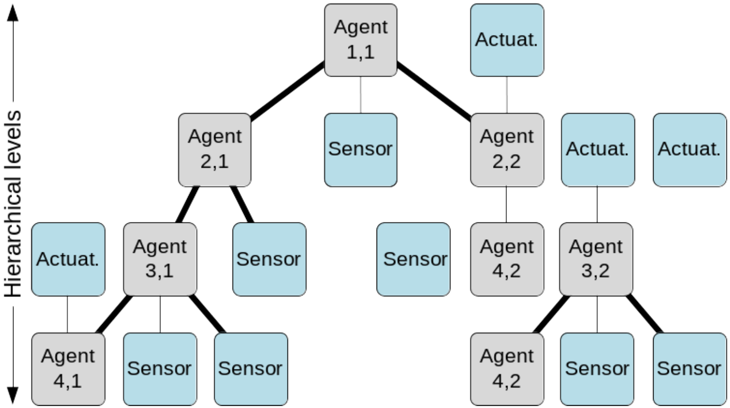


Smart Grid Monitoring - Summary and Outlook

- Can operate on top of existing infrastructure
- Allows for monitoring of live data stream
- Further field tests based on real data
- Consider more heterogeneous data (e.g., weather data)
- Inclusion of our monitoring approach into simulation
- Implementation on different cloud and edge devices

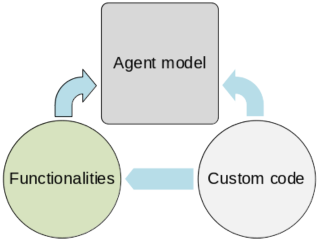
RoSA Framework

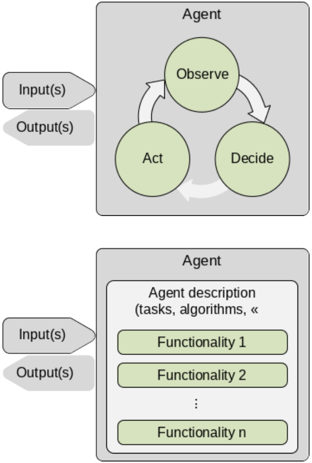
RoSA - Research on Self-Aware Monitoring



Open-source implementation is available at
`https://phabricator.ict.tuwien.ac.at/source/SoC_Rosa_repo.git`

Maximilian Götzinger et al. "RoSA: A Framework for Modeling Self-Awareness in Cyber-Physical Systems". In: *IEEE Access* 8 (2020)

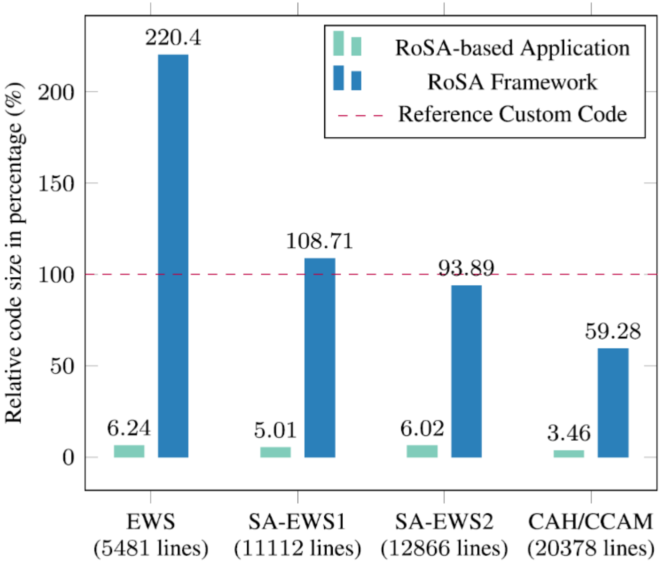

Agent model
Functionalities
Custom code


Agent
Input(s)
Output(s)
Observe
Act
Decide
Agent
Agent description
(tasks, algorithms, «
Input(s)
Output(s)
Functionality 1
Functionality 2
⋮
Functionality n

Metrics	EWS			SA-EWS 1			SA-EWS 2			CAH/CCAM		
Cortex-	A7	A15	A53	A7	A15	A53	A7	A15	A53	A7	A15	A53
Executable Binary Size (kB)	798	798	817	911	911	933	1079	1079	1105	662	662	678
Maximum Allocated Memory* (kB)	3508	3508	3272	3584	3584	3440	3656	3656	3624	3348	3348	3404
Average Sample Processing Time** (ms)	0.46	0.22	0.39	0.74	0.35	0.64	1.64	0.77	1.50	7.41	4.37	7.21
Real-Time Sampling Period*** (ms)	1000	1000	1000	1000	1000	1000	1000	1000	1000	33	33	33

* Memory size includes code and all data during execution.
** The average is based on the total processing time including initialization of the application and reading sensor input files and writing output file, in single-threaded execution.
*** Maximum acceptable sample processing time for real-time execution based on application requirements.

RoSA - Research on Self-Aware Monitoring



Summary and Conclusion

Context Aware Monitoring - Summary

- Intelligent monitoring is based on several general concepts
- The same concepts are applicable on a range of application domains with small to medium adaptation
- RoSA and CCAM are general purpose modeling and monitoring tools
- Case studies: industrial motor, water pipe system, medical monitoring, smart grids

¿ Questions ?