BladeWatch

Increasing Wind Power Availability through Energy-Autonomous Wireless Smart Sensors

Lukas Hanna [1], Manfred Mücke [1], Christoph Gratl [1], Franz-Martin Frieß [1], Elisabeth Hieslmayr [1]

[1] Materials Center Leoben Forschung GmbH

Abstract

Wind turbine condition monitoring systems (CMS) are crucial for maximizing turbine up-time. Especially for blade monitoring, wired sensor are not acceptable. Wireless sensor nodes (WSNs) exist, but harvested energy is insufficient for continuous high-frequency sampling and sending. Modern machine learning algorithms/models can significantly reduce the amount of communication by computing partly on the WSN. Yielding a solid estimate of consumed energy under different solar irradiance, wind and fault conditions is not trivial, though. The BladeWatch project creates a software framework (WSN*Explorer) for power budget estimation of WSN-based CMS to bridge the gap between algorithmic research and system design. The WSN*Explorer enables CMS designers to map a large number of design options efficiently.

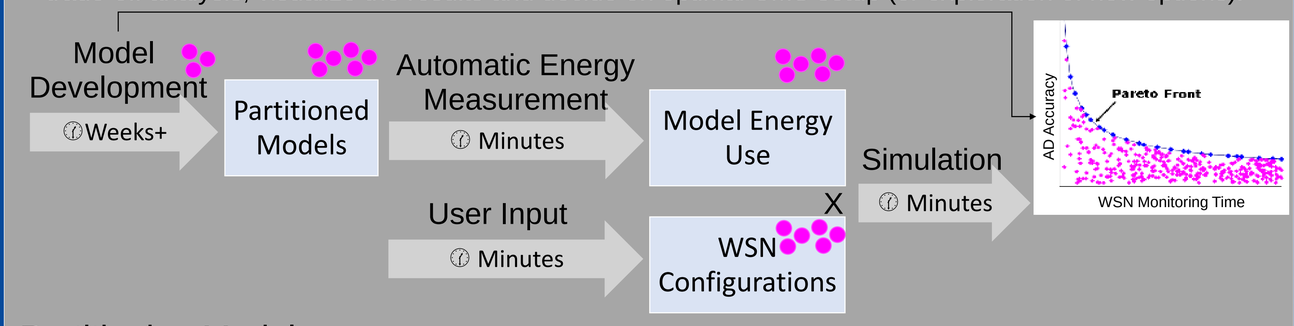
Problem: Finding the right WSN configuration to maximise fault detection accuracy and monitoring time

Many possible WSN configurations:

There exist many possible WSN configurations with different choices in hardware (battery size, solar panel size and type, RF link, antenna configuration …) and software (sensor sampling frequency, sleep time between sensing activity, anomaly detection models **(ADMs)**, partial execution on WSN..). Every combination of hardware and software choices can result in different power consumption and therefore in different monitoring times before running out of energy.

Solution: Mapping configurations and automatic energy measurement of partitioned ML ADMs

To yield a large number of model options for **trade-off analysis** of **accuracy** and **WSN monitoring time**, models need to be **partitionable** (WSN<>Base station) and their **energy consumption** be **automatically evaluated**. The WSN*Explorer (see lower box) allows CMS designers to quickly perform trade-off analysis, visualize the results and decide on optimal CMS setup (or exploration of new options).

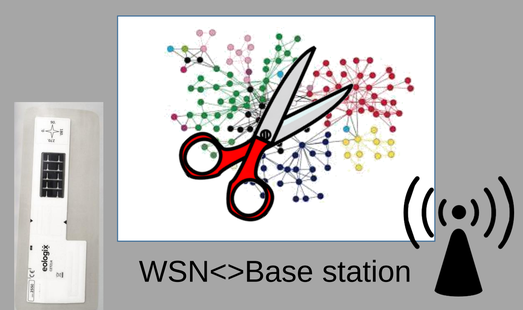


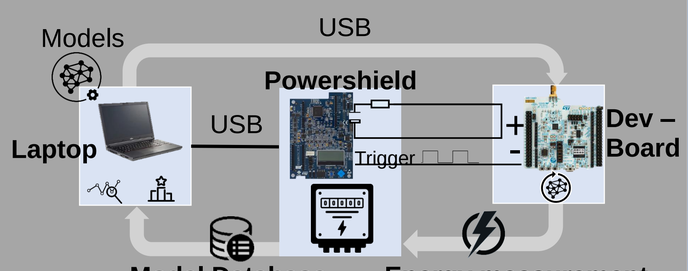
Partitioning Models:

Partitioning means splitting computational load of the model into WSN and base station parts. Partitioning anomaly detection **machine learning (ML)** models can potentially reduce data to be transmitted and therefore could save energy. **One main goal is to find the optimal partition.**

Automatic Energy Measurement:

A setup to automatically analyze the power consumption of many model and algorithms. The developed models are automatically deployed and executed a dev board while the power shield measures the energy consumption. Results are fed to the WSN*Explorer (see next box).

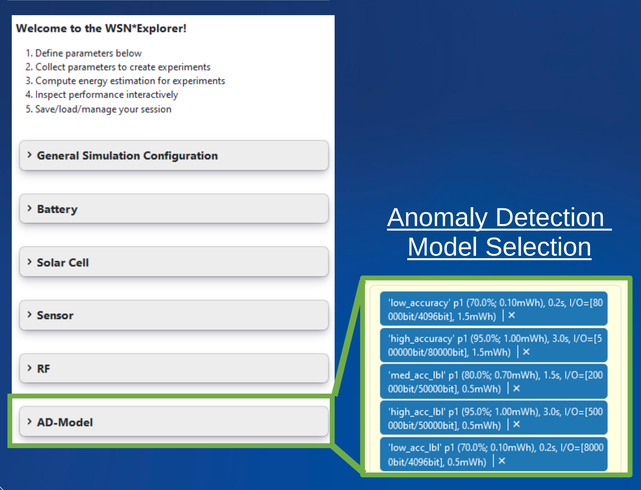




WSN*Explorer: A Software to Simulate WSNs & Algorithms Under Different Environmental Conditions

The machine learning model metrics such as accuracy and energy consumption are supplied to the simulation and can be selected with other WSN parameters like battery size and solar cell size as well as general parameters such as location (for solar irradiation) and a specific date range. All selected parameters are then combined into many experiments (each with an unique parameter set) and simulated. The results for each experiment are various metrics e.g. energy consumption or achievable monitoring time.

Parameter Selection:



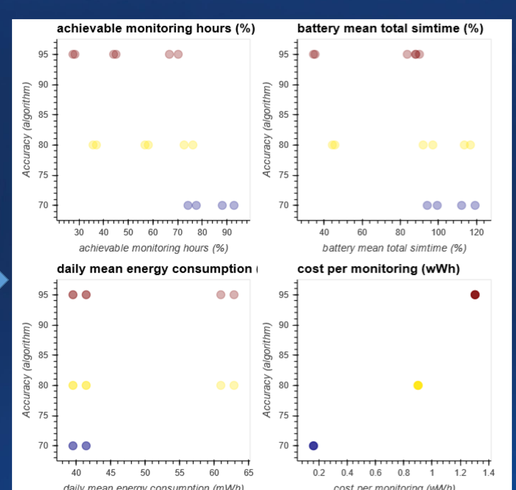
Anomaly Detection Model Selection

Combine into Parameter Sets
One Parameter Set = One Simulation

Run	Accuracy (algorithm)	Energy consumption (algorithm)	Algorithm	Partition (algorithm)	Location Description	Days simulated	Experiment Name	achievable monitoring hours (h)	achievable monitoring hours (%)	total runtime hours (h)	failed monitoring hours (h)	battery minimum total simtime (mWh)
✓	95	1.0	high_acc_lbl	1	Stockholm	7	exp_-42_2_280524122959	168	100	168	0	82
✓	95	1.0	high_accuracy	1	Stockholm	7	exp_-25_2_280524105945	46	27.5793	168	122	0
✓	95	1.0	high_accuracy	1	Stockholm	7	exp_-25_6_280524105945	112	66.8666	168	56	0
✓	95	1.0	high_accuracy	1	Stockholm	7	exp_-25_10_280524105945	48	28.3730	168	120	0
✓	70	0.1	low_acc_lbl	1	Stockholm	7	exp_-42_3_280524122959	168	100	168	0	178
✓	70	0.1	low_accuracy	1	Stockholm	7	exp_-25_1_280524105945	125	74.2063	168	43	0
✓	70	0.1	low_accuracy	1	Stockholm	7	exp_-25_5_280524105945	148	88.0952	168	20	0
✓	70	0.1	low_accuracy	1	Stockholm	7	exp_-25_9_280524105945	130	77.5793	168	38	0
✓	70	0.1	low_accuracy	1	Stockholm	7	exp_-25_13_280524105945	156	92.8571	168	12	0
✓	80	0.7	med_acc	1	Stockholm	7	exp_-25_3_280524105945	60	35.7142	168	108	0

visualize results

each experiment is a point



Each color is an Anomaly Detection Model with different WSN configurations.

The overview makes it easy to compare and select the appropriate options.

Summary

- BladeWatch develops a software framework (WSN*Explorer) for power budget estimation of WSN-based CMS
- BladeWatch bridges the gap between algorithmic research and system design for energy-autonomous WSN-based CMS
- BladeWatch enables efficient mapping of design options across SW/Algorithm and HW choices.

Partners:

eologix sensor technology
https://www.eologix-ping.com/

KNOW Center
https://www.know-center.at/

BladeWatch:
https://projekte.ffg.at/projekt/4352938

Acknowledgement:

FFG Forschung wirkt.

Die FFG ist die zentrale nationale Förderorganisation und stärkt Österreichs Innovationskraft. Dieses Projekt wird aus Mitteln der FFG gefördert. www.ffg.at

MATERIALS CENTER LEOBEN FORSCHUNG GMBH

Contacts:
lukas.hanna@mcl.at
manfred.muecke@mcl.at