Data Sensing and Fusing for Production Machinery Maintenance: Digital Assistance with Post-Analysis, Diagnostics and Prognostics

Keynote

The Fifteenth International Conference on
Mobile Ubiquitous Computing, Systems, Services and Technologies

UBICOMM 2021

October 3-7, 2021 - Barcelona, Spain

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Keynote Presenter

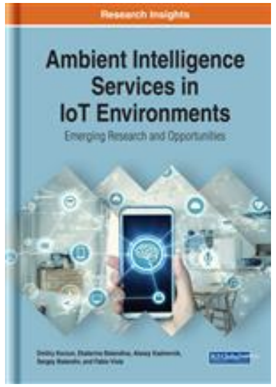
Dmitry Korzun received his B.Sc. (1997) and M.Sc. (1999) degrees in Applied Mathematics and Computer Science from the Petrozavodsk State University (PetrSU, Russia). He received a Ph.D. degree in Physics and Mathematics from the St.-Petersburg State University (Russia) in 2002.

His educational activity started in 1997 at the Faculty of Mathematics of PetrSU (now Institute of Mathematics and Information Technology). He is an Adjunct Professor at Department of Computer Science of PetrSU (since 2003 and ongoing). He was a Visiting Research Scientist at the Helsinki Institute for Information Technology HIIT, Aalto University, Finland (2005-2014). In 2014-2016 he performed the duties of Vice-dean for Research at Faculty of Mathematics and Information Technology of PetrSU.

Since 2014 he has acted as Leading Research Scientist at PetrSU, originating research and development activity within fundamental and applied research projects on emerging topics in ubiquitous computing, Internet technology, and Ambient Intelligence. Since 2019 he has been the head of Data Mining Lab at PetrSU. Since 2020 he has been the Deputy Director for Research of Artificial Intelligence Center. Dmitry Korzun serves on technical program committees and editorial boards of 100+ of international conferences and journals. He is an author and co-author of 200+ research and educational publications. He has published several monographs in Springer and IGI Global. He is also Guest Editor of special issues in many international journals. Since 2010 Dmitry Korzun have been participated in UBICOMM.

Enablers

- Discussion from AmIIoTE Special Track at UBICOMM 2020
  - AmIIoTE: Ambient Intelligence in IoT Environments + Tutorial



- Concepts from the book
  - on the topic "Ambient Intelligence Services in IoT Environments: Emerging Research and Opportunities"
  - by Dmitry Korzun (PetrSU), Ekaterina Balandina (TUT), Alexey Kashevnik (SPIIRAS), Sergey Balandin (FRUCT), Fabio Viola (UniBo)

- Latest solutions from the R&D project (2019-2021)
  - on the topic "Creating the high-tech production of mobile microprocessor computing modules based on SiP and PoP technology for smart data collection, mining, and interaction with surrounding sources"
  - implemented in Petrozavodsk State University with financial support by the Ministry of Science and Higher Education of Russia within Agreement no. 075-11-2019-088 of 20.12.2019

Industrial systems

- Production Machinery Maintenance
- Use case: Technical state and operation condition
  - bearing fault detection and classification
  - High-rate fault detection
  - Low-rate defect classification
  - Each machinery unit is unique
  - No much data labeled with fault information for training

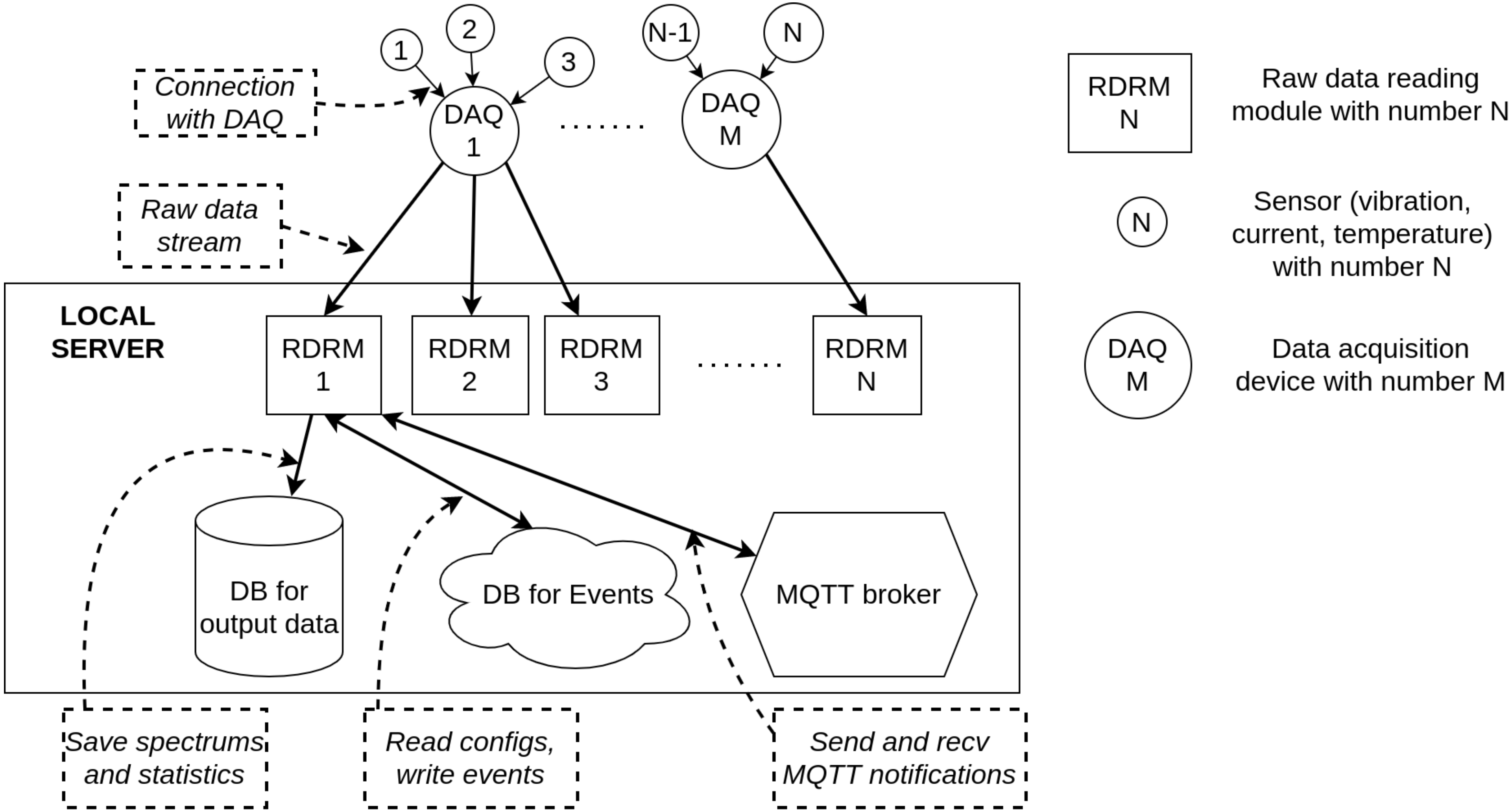
Real-time data analytics

Analytical services for digital assistance in production machinery maintenance

- post analysis (descriptive retrospective)
  - statistics and time plots on past data
- diagnostics
  - explanation why something happened in the past
- prognostics
  - recommendations based on what is most likely to happen in the future

Sensing Multi-Source Data

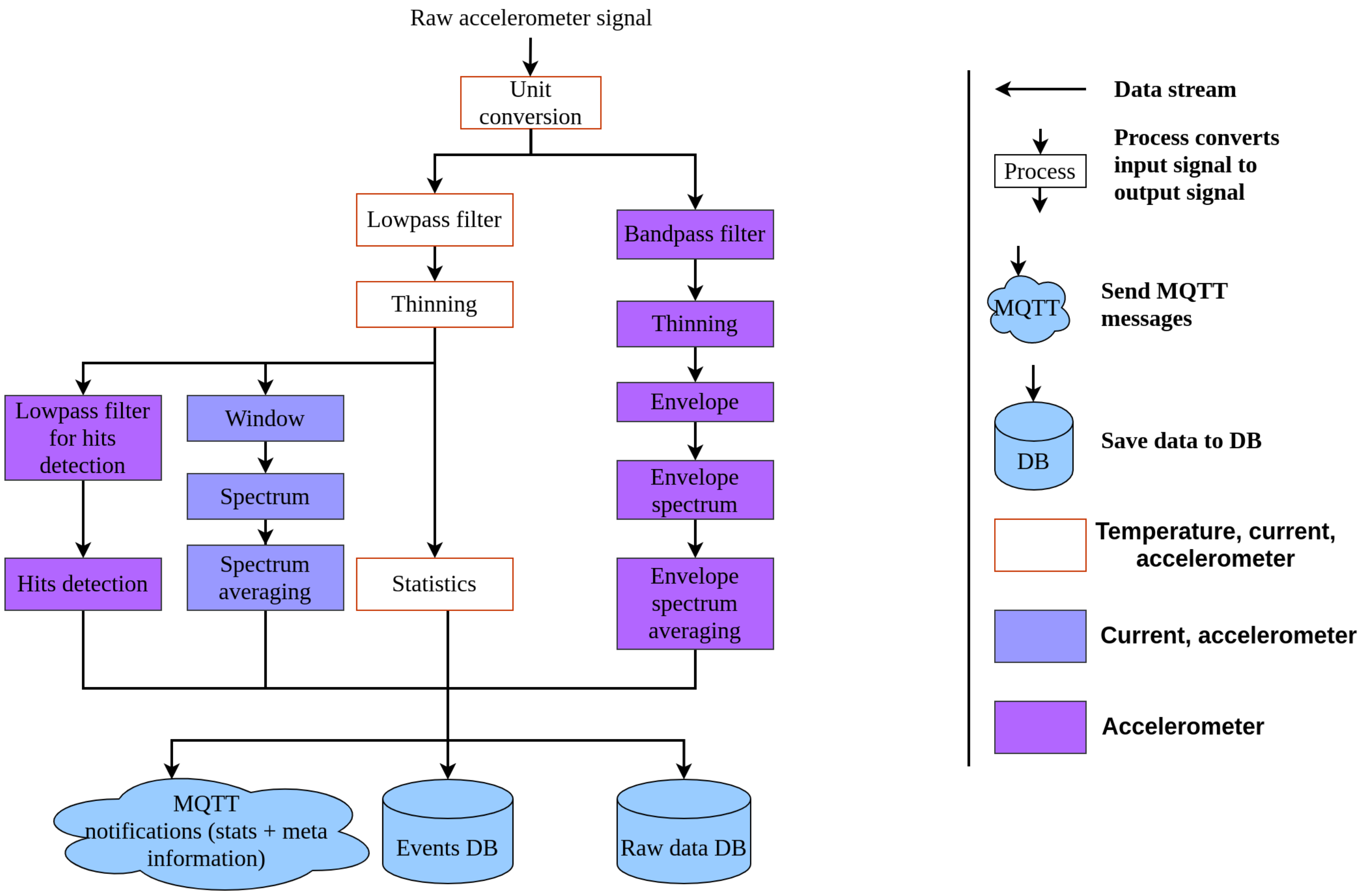
- up to N=6 sensors per data acquisition device (DAQ)
- Many DAQs are possible to be in the system



Vibration Case Study

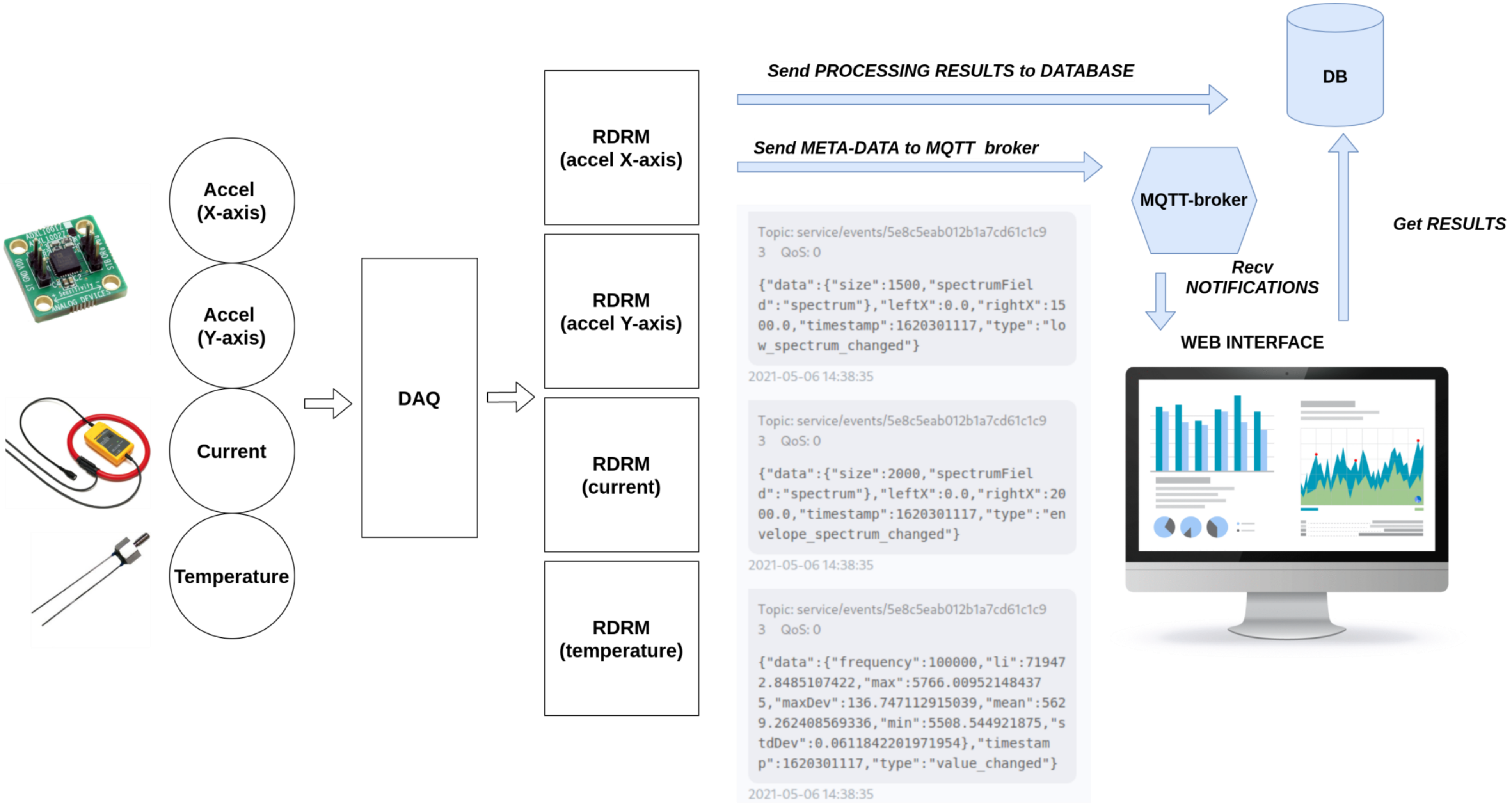
- Accelerometer
- High-speed data (high rate)
- Signal analysis:

  Well-known mathematical models and algorithms
- Typical statistics



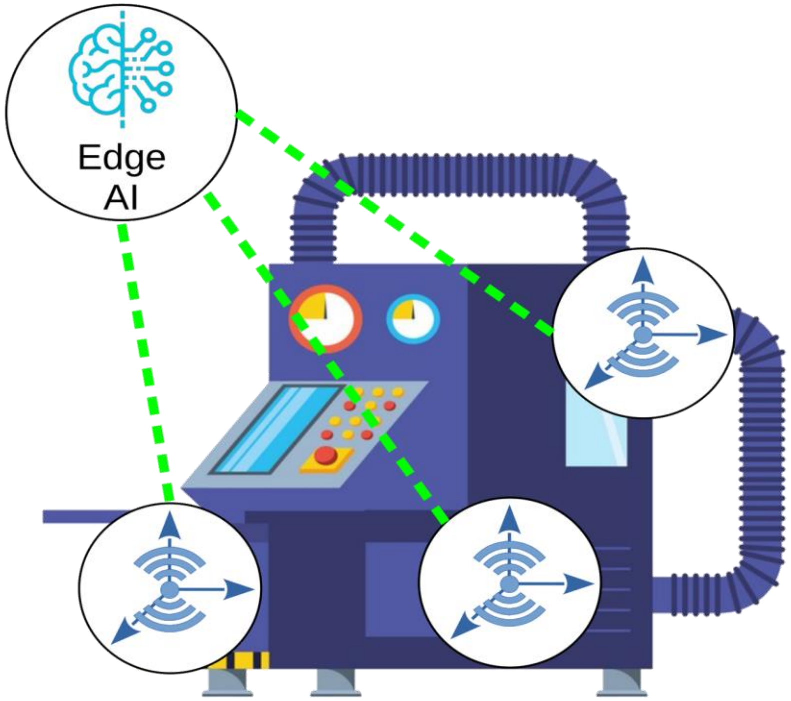
Data Fusion: Making a Digital Model

- Digital model to describe the technical state, utilization conditions, and underlying manufacturing processes
- Based on analytics from multiple sensed data flows



Edge Computing

- Condition monitoring of industrial equipment
- Data processing is near the equipment location
- Benefits
  - early detection of equipment malfunctions,
  - staff scheduling efficiency increase,
  - cost reduction,
  - fast accidents prevention.
- Edge-centric processors:
  - knowledge processors – as it happens in Smart Spaces and Multi-Agent Systems
  - embedded or mobile accelerators for neural network computations in data processing

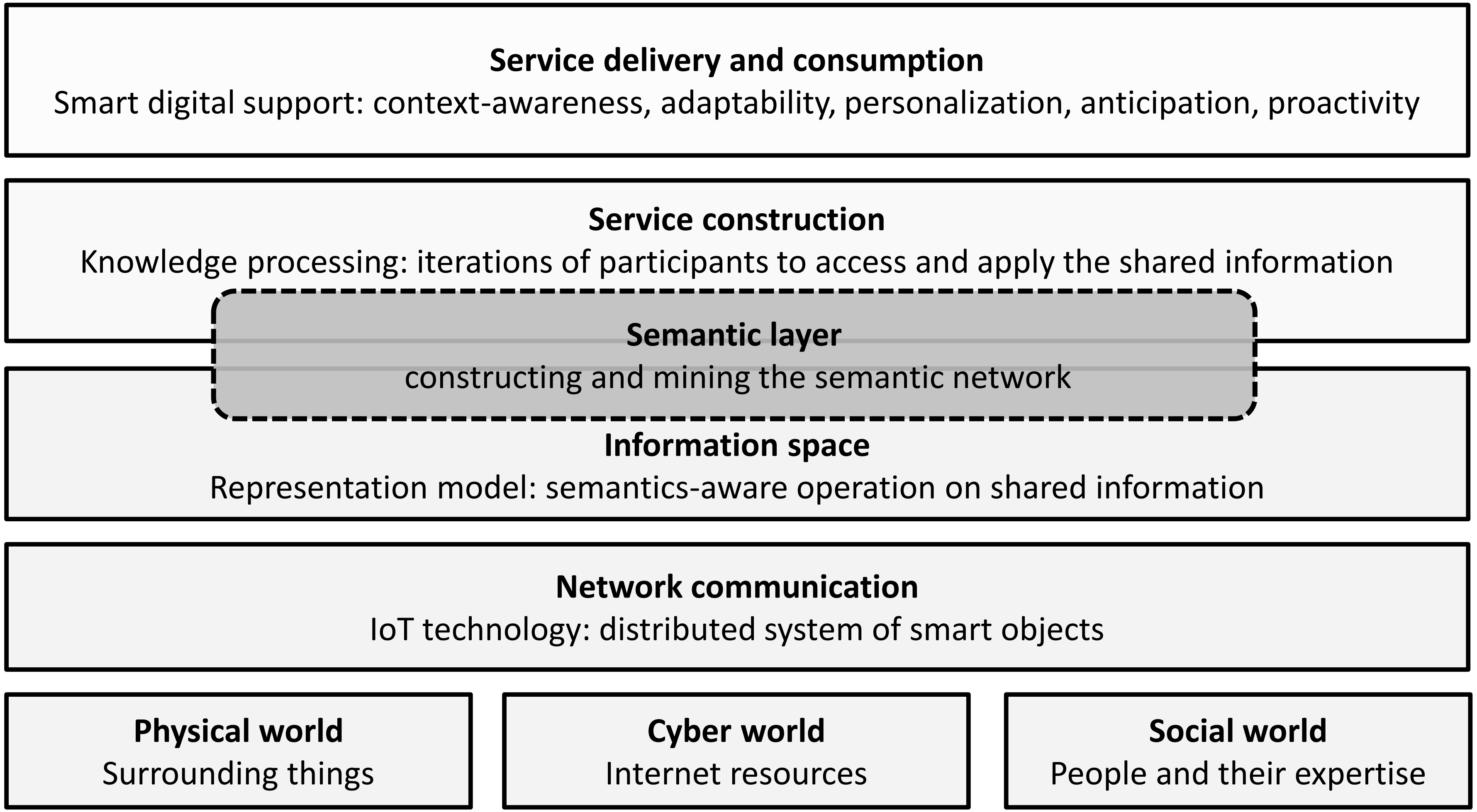


Modular System: Smart Sensing at IoT Edge

- Sensing Computing Module (SCM)
  - universal in terms of supported sensors and sensed data types
- Control Computing Module (CCM)
  - central processing unit for edge-centric data processing of incoming data flows from Sensing Module
- Tensor Computing Module (TCM)
  - Neural Network accelerator for data processing tasks delegated by CCM
- Data Storage Module (DSM)
  - high-speed local data base
- Data Communication Module (DCM)
  - IoT-related data exchange in Modular System
- Innovative Product:
  - ***Modular System for Information Collection and Analysis (MSICA)***
  - ***Can be used to develop various monitoring systems with digital analytical services for smart assistance***

Concept Layers for Information Life-Time

- In digital analytical services for smart assistance



Digital Analytical Services: Examples

- Unit of production machinery:
  - show statistics on the past and current status
  - in real time, for mobile personnel, in dashboard, Augmented Reality, …
- Notifications on possible abnormal situations
  - speedup of the recovery processes
- Assistant in fault diagnostics for a given unit of production machinery
  - help to show possible problems and reasons
- Evaluation of Remaining Useful Life
  - predictive maintenance becomes possible
- and many others …

Approach to Service Construction

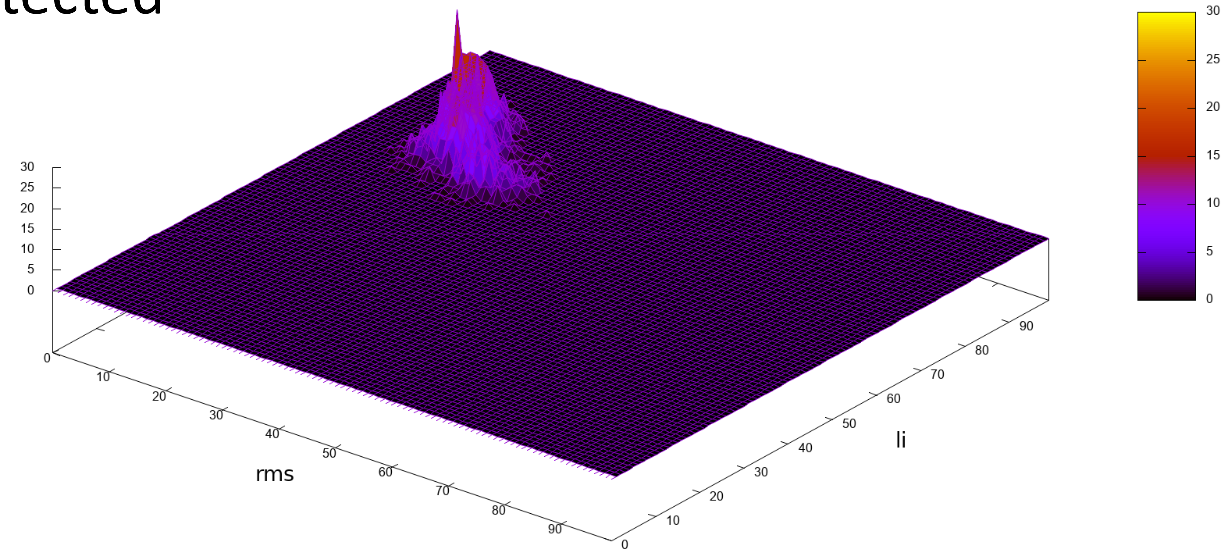
- Multi-layer Fusing the sensed data from multiple sources
  1. Deviation Model
  2. Event-Driven Model
  3. Fault Detection Model
  4. Fault Evolution Model

  \+ Machine Learning Model
- Each layer provides new knowledge on the objects and processes under monitoring

Deviation Model

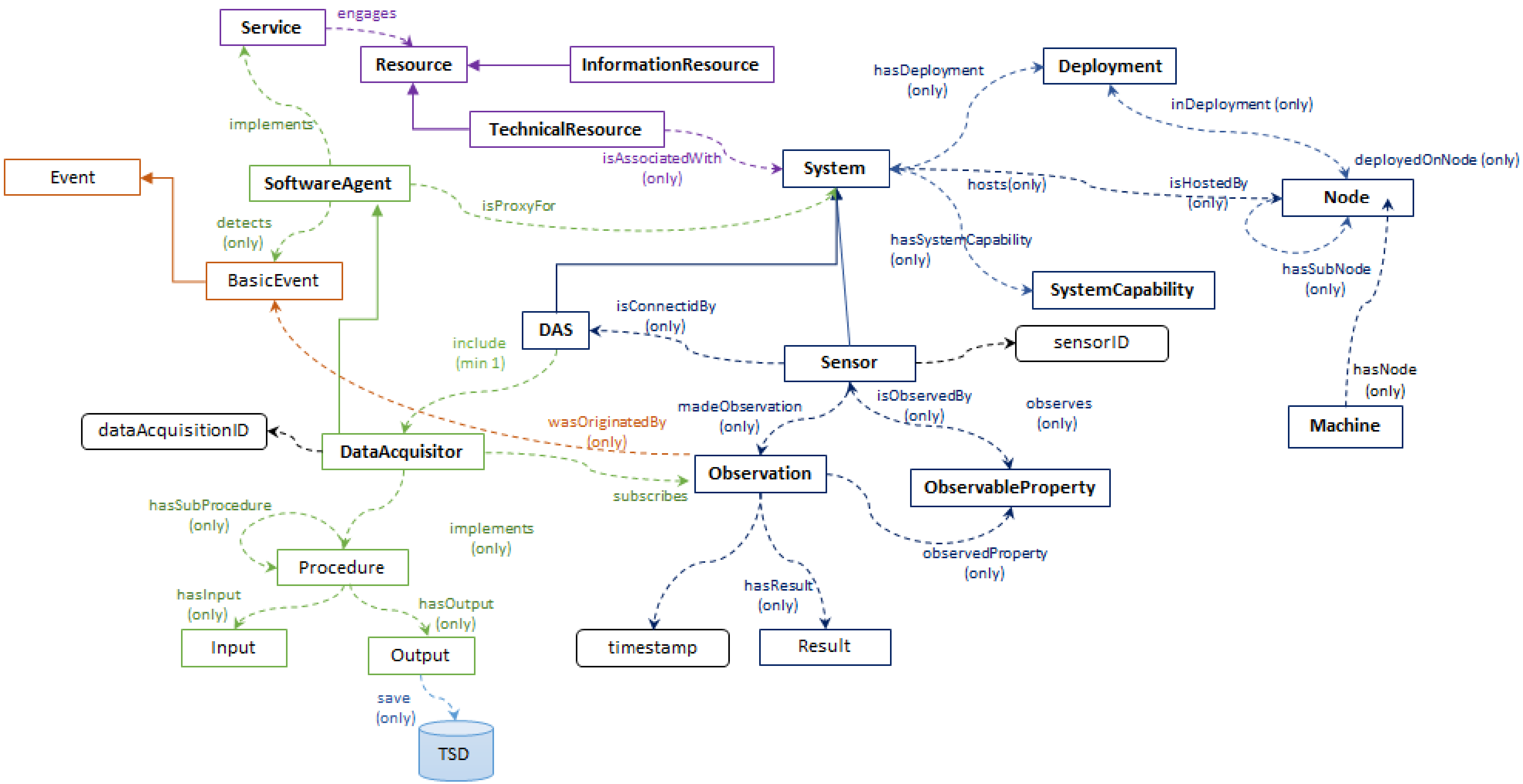
- Create a machinery unit profile with unlabeled sensed data
  - Adaptation mode - reference digital profile construction with data from various sensors: $\mathbf{P}_{ref}$
  - Control mode. Deviation detection by applying a comparison reference profile with the current observation:

if $|P_{cur}(t_i) - P_{ref}| > \varepsilon$ then deviation is detected



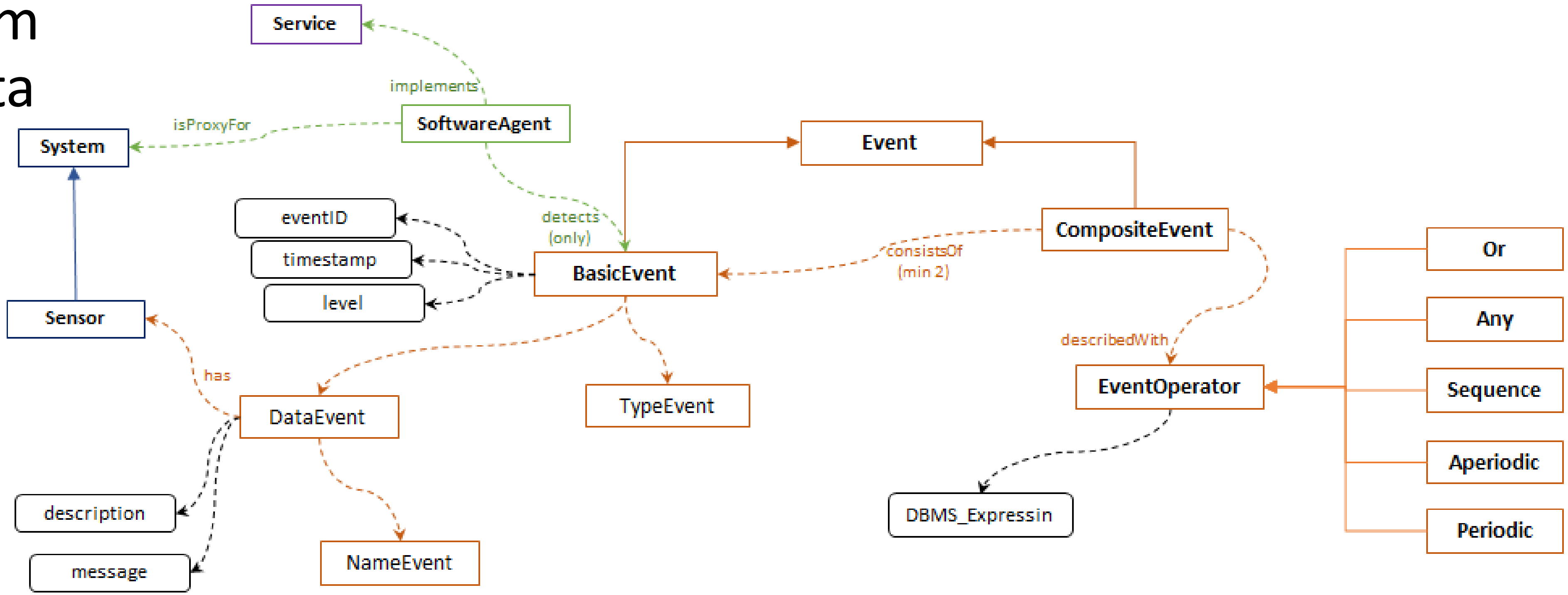
Event-Driven Model: Domain

- Production machinery domain
- Ontology to describe problem domain
- Basic entities and relations
- One constructs own ontology for the particular problem



Event-Driven Model: Events

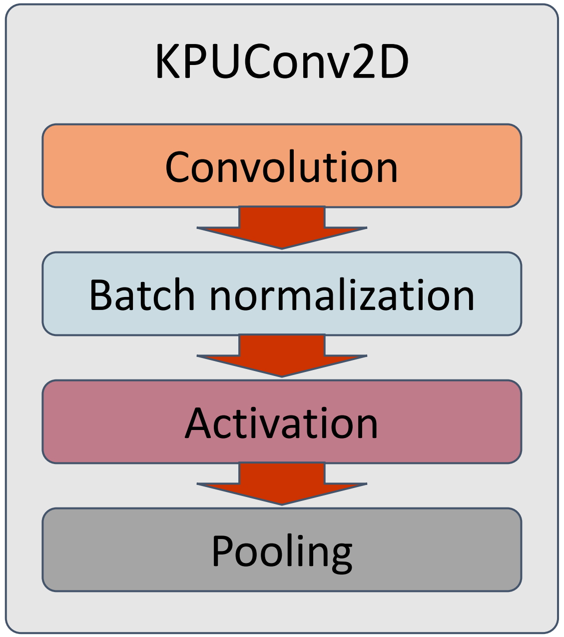
- Many events from many sensed data sources
- Event ID + Timestamp
- Importance:
  - no problem
  - weak problem
  - medium problem
  - strong problem
- Composite events

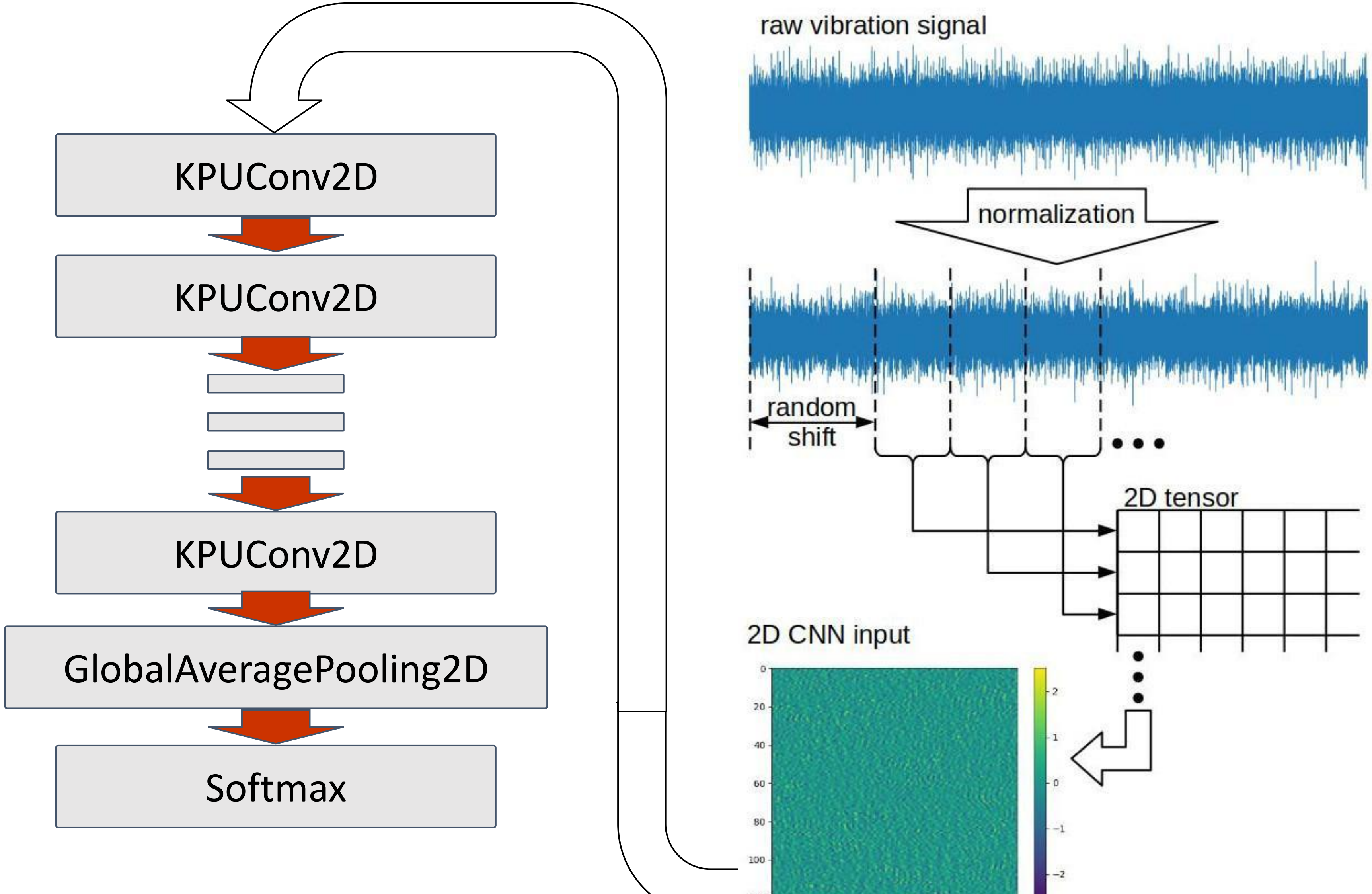


Fault Detection Model

Diagnosis based on Convolution Neural Network. Use case: Bearing Fault Diagnosis

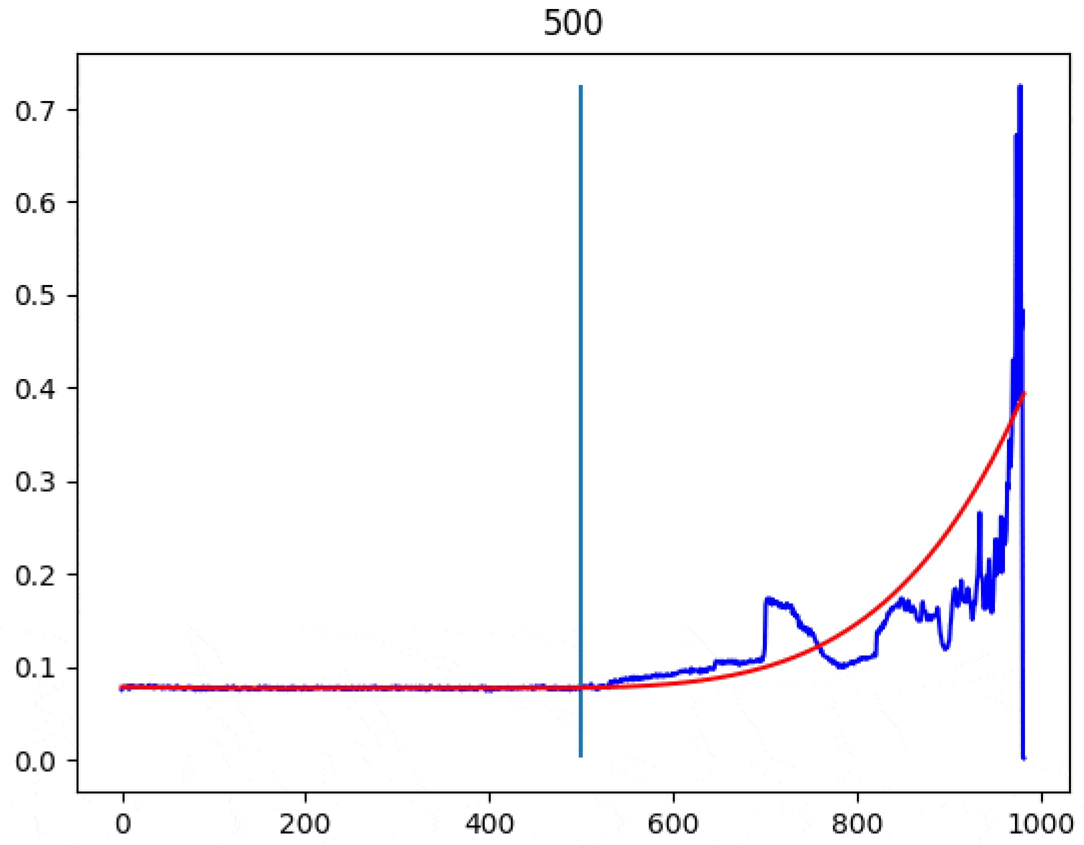
Elementary hardware accelerated operation





Fault Evolution Model

- Trend analysis
- Extrapolation is constructed and updated based on observed history and latest sensed data



Machine Learning Model

- When anormal situation is detected then operator analyzes the case
- The labeled data are produced for further training the fault detection model
- Human assists to her/his digital assistant

Conclusion

- Our approach to Digital Assistance with Post-Analysis, Diagnostics and Prognostics
- Our case study: Production Machinery Maintenance
- Based on: Multi-layer Fusing the sensed data from multiple sources

Thank you!

Forward your questions and comments to dkorzun@cs.karelia.ru