



Health-eTile
healthetile.io



Revolutionizing Smart Health Research: Bringing Smart Devices with Integrated AI to the Wild

Houman Homayoun

2024 TinyML Research Symposium



Talk Outline

Area of Smart Health and AI

Researcher Needs in This Area

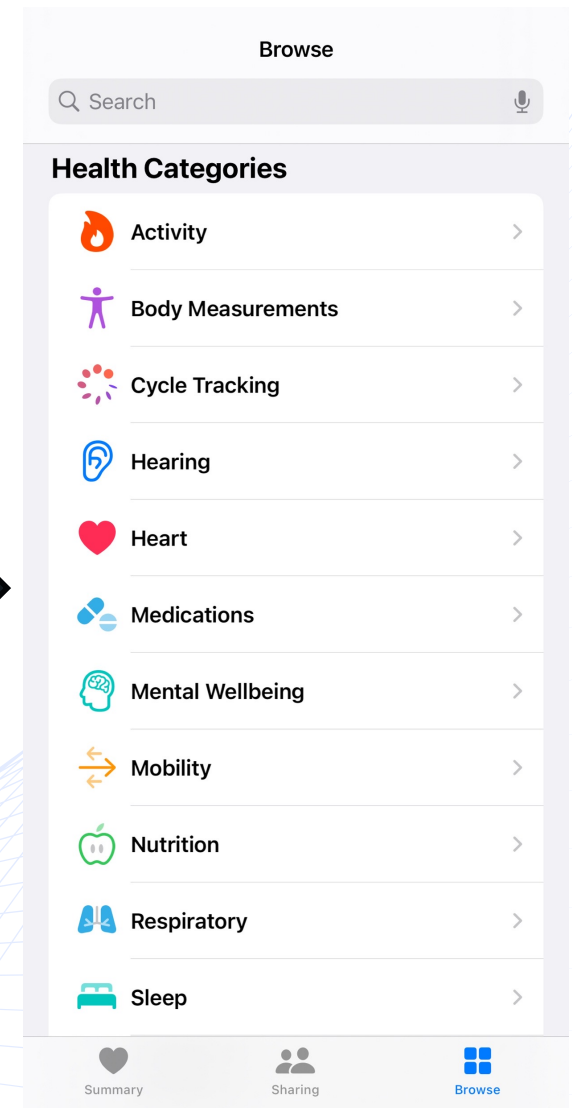
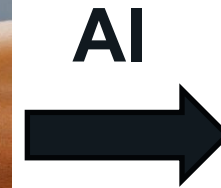
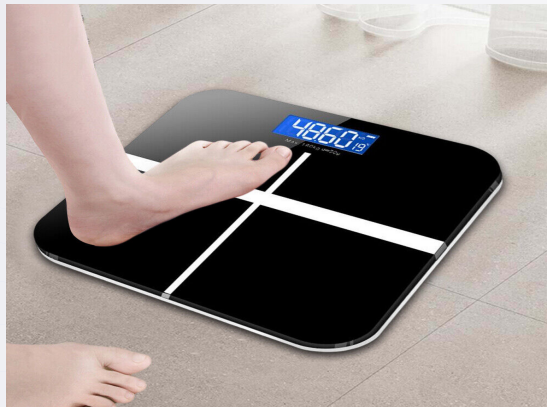
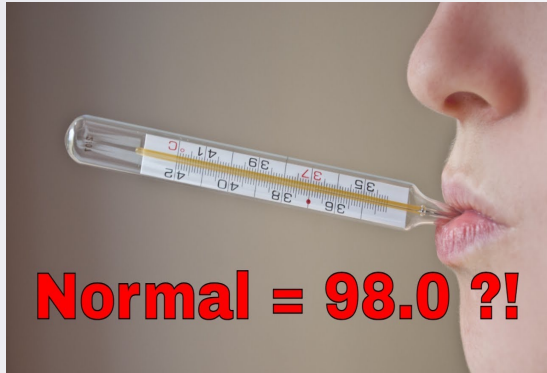
What We-Be Ecosystem Offers

Importance of Accessing to a Full Stack System

Deploying and Testing TinyML in We-Be



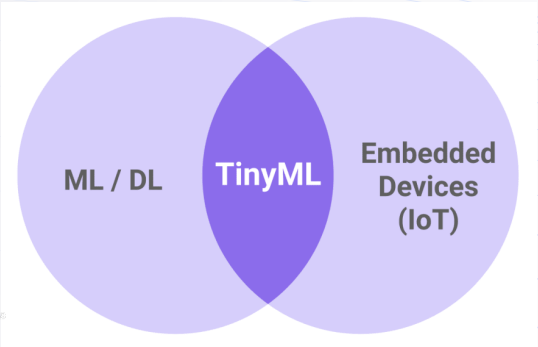
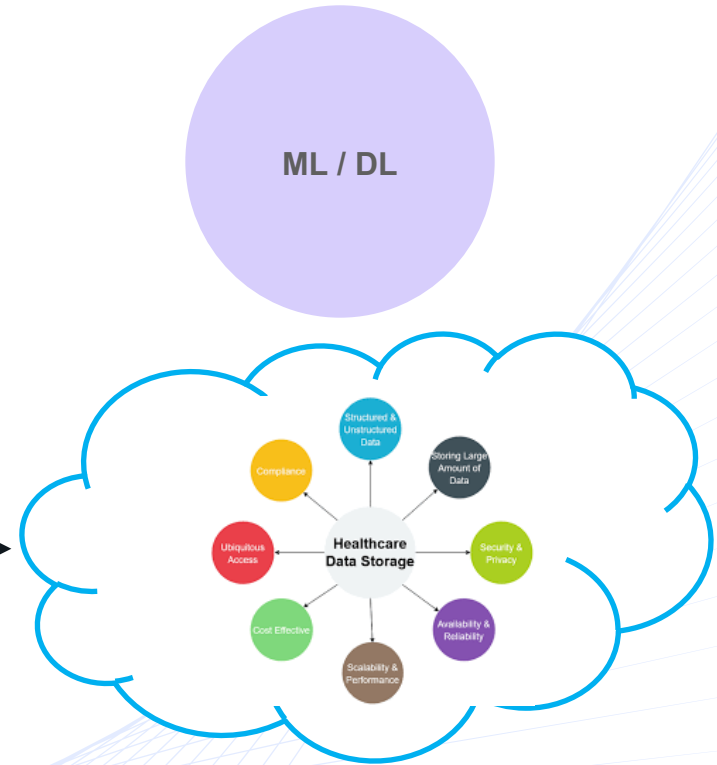
Transforming Healthcare with AI-Enabled Wearables



The Power of TinyML in Wearables

The Future of Machine Learning is Bright and Tiny!

https://www.tinkerden.com/wio_terminal



infection disease
anemia
type 2 diabetes
cancer



Researcher Needs in Smart Health Area



Consumer Grade Wearables in Health Domain



Google

SAMSUNG

GARMIN™



xiaomi



Needs for Researchers

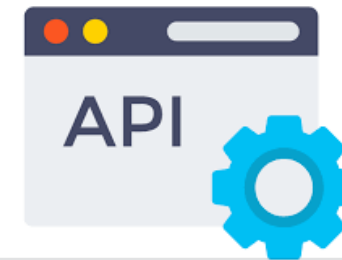
Signal Waveform /
Raw data



Diversity of Sensors



API/SDK



Monitoring

Continuous vs Episodic



Needs for Researchers

Form Factor



Battery Lifetime

One day

Software Pipeline

~~X~~ Dashboard

~~X~~ Signal Processing Box

~~X~~ Mobile App

~~X~~ Auto-ML

Cost



Deploying ML

end-to-end access for deploying tinymml and testing, measuring the power/performance



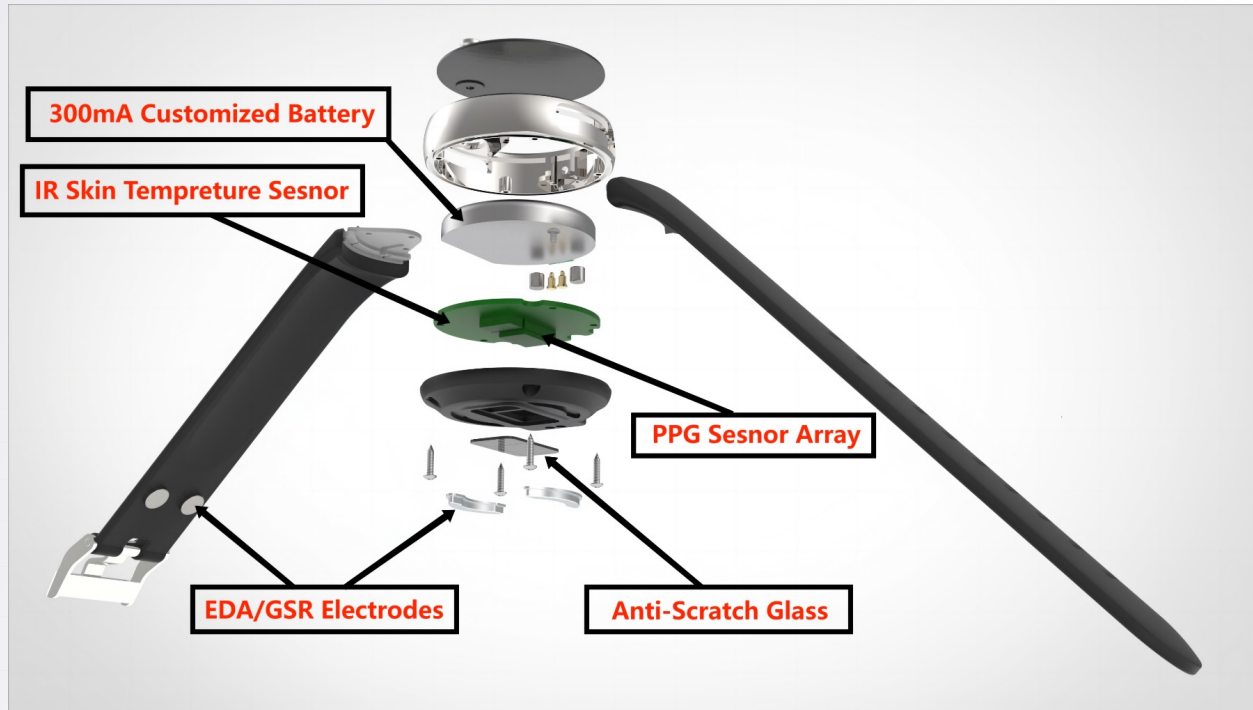
What We-Be Ecosystem Offers



We-Be Band

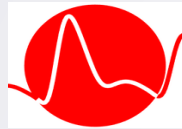
Bring laboratory to everywhere

We-Be is a new generation wearable watch equipped with multiple vital sign sensors. It seamlessly outputs clean raw data waveform which is accessed through in cloud and everywhere. It has an Open-API to create user specific application.



We-Be Band Features

We-Be band is equipped with medical grade sensors and multiple user-friendly features for research projects!



PPG Sensor

Heart rate, heart rate variability, SpO2 monitor



Long Battery Life

With the optimized hardware and firmware developed, We-Be has up to two weeks battery life.



Stress Detection

We-Be band is equipped with most advanced machine learning-based stress detection model. The model analyzes hundreds of features from PPG, EDA sensors to be aware of the accurate stress level.



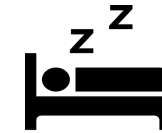
EDA Sensor

perspiration of hands, which can be a marker for stress



Event button

Event button on the band as well as mobile device enables easy event mark down. Easy for labeling the data.



Sleep Track

We-Be monitors an impressive array of metrics to evaluate user's sleep time and sleep quality.



3-axis Accelerometer

Track daily activities (steps, calories, cadence)



Seamless

We-Be uses Bluetooth Low Energy protocol and offers seamless connection and low-latency data transmission.



Blood Pressure Simulation

With advanced AI/ML techniques, blood pressure is able to be simulated on wearable, We-Be!



Temperature

Measures skin temperature



Offline storage

When disconnected with phone/PC, the device will automatically store data of up to 30 hours to avoid data loss.



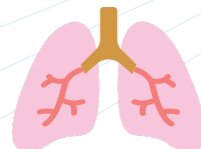
Sports Coach

We-Be tracks activity, walk steps, run steps, and calory consumed and provides detailed analysis sports report and advice.



Signal Pre-process

Besides raw data, we provide pre-processed data containing well-denoised signals and comprehensive extracted features in time-, frequency, time-frequency- and non-linear domain.



Respiratory Rate

We deployed state-of-the-art PPG-based respiratory rate estimation algorithms.



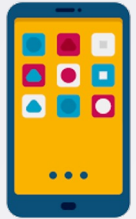
Calory

We-Be measures user's calory consumption and provides diet advice.

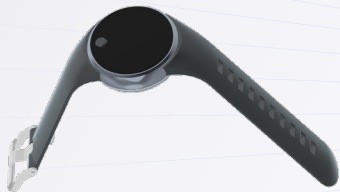
Web Dash Development



Web Dash



Cloud



We-BE Band



ML API



Health eFile

Shivani Sharma

Patients (25)

Search

Add Patient +

SI No	Name	Device ID	Email ID	Password	Action
1	Austin Hunt	ID987654	Dummyemail@gmail.com	password123	
2	Austin Hunt	ID987654	Dummyemail@gmail.com	password123	
3	Austin Hunt	ID987654	Dummyemail@gmail.com	password123	
4	Kate Cross	ID987654	Dummyemail@gmail.com	password123	
5	Kate Cross	ID987654	Dummyemail@gmail.com	password123	
6	Kate Cross	ID987654	Dummyemail@gmail.com	password123	
7	Kate Cross	ID987654	Dummyemail@gmail.com	password123	

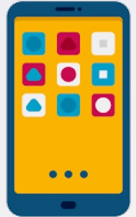
« Previous 1 2 3 ... 10 Next »

Subjects Management

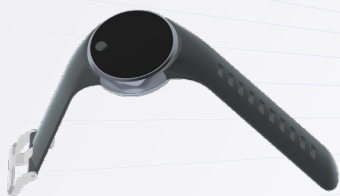
Web Dash Development



Web Dash



Cloud



We-Be Band



ML API



Healthcare Professionals

Health efile

Shivani Sharma

Patients (25)

Search Add Patient +

Sl No	Name	Device ID	Email ID	Password	Action
1	Austin Hunt	ID987654	Dummyemail@gmail.com	password123	
2	Austin Hunt	ID987654	Dummyemail@gmail.com	password123	
3	Austin Hunt	ID987654	Dummyemail@gmail.com	password123	
4	Kate Cross	ID987654	Dummyemail@gmail.com	password123	
5	Kate Cross	ID987654	Dummyemail@gmail.com	password123	
6	Kate Cross	ID987654	Dummyemail@gmail.com	password123	
7	Kate Cross	ID987654	Dummyemail@gmail.com	password123	

« Previous 1 **2** 3 10 Next »

Notes ×

Previous Notes

Lorem Ipsum is simply dummy text of the printing and typesetting industry. Lorem Ipsum has been the industry's standard dummy text

04/03/2024,10:31 AM

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05/03/2024,10:31 AM

Add Notes

Notes

Notes

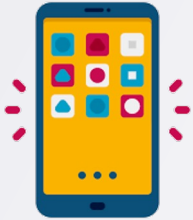
Add

Added Notes and Questionnaire

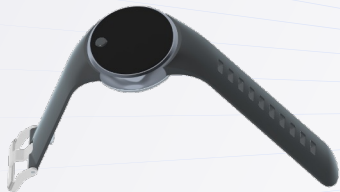
Web Dash Development



Web Dash



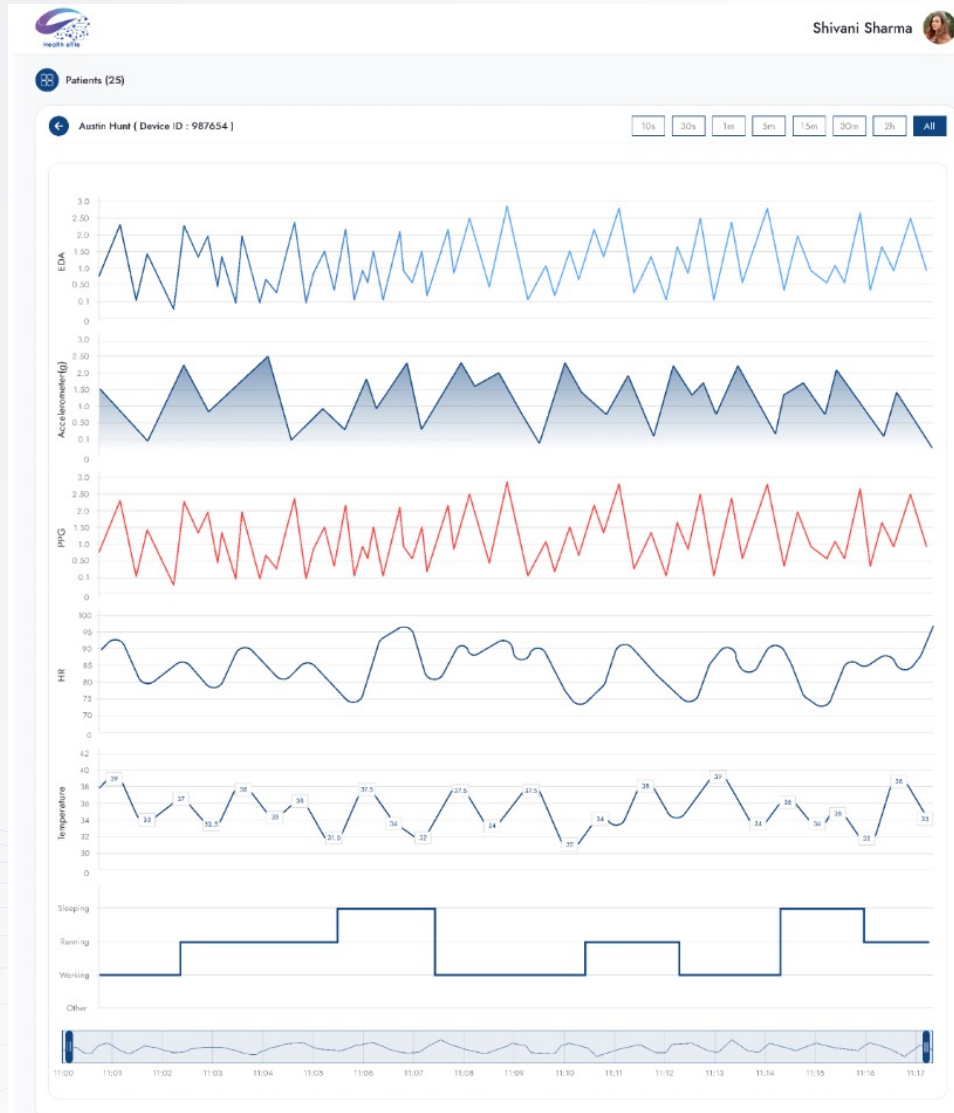
Cloud



We-Be Band



ML API



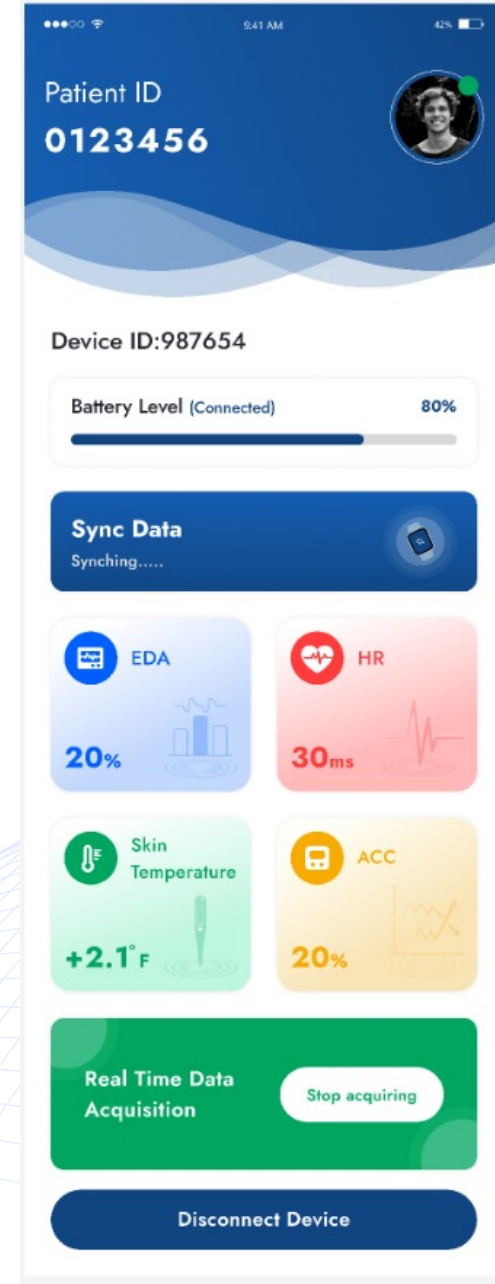
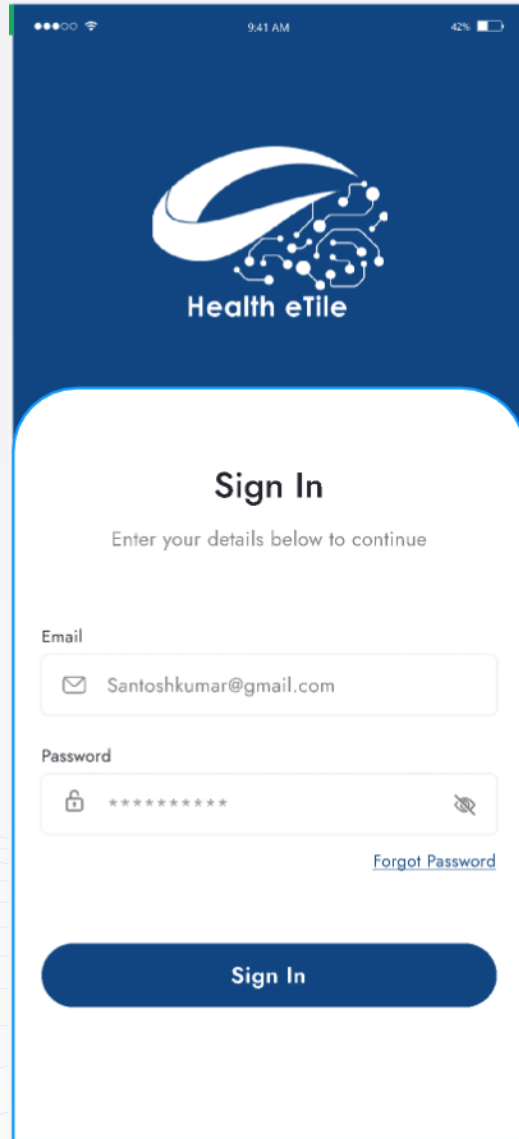
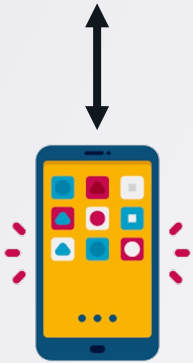
Waveform Display

Subject Information Management

Mobile Application Development



ML API



Importance of Accessing to Full Stack System for Smart Health Research



TinyML Development Frameworks

Edge Impulse

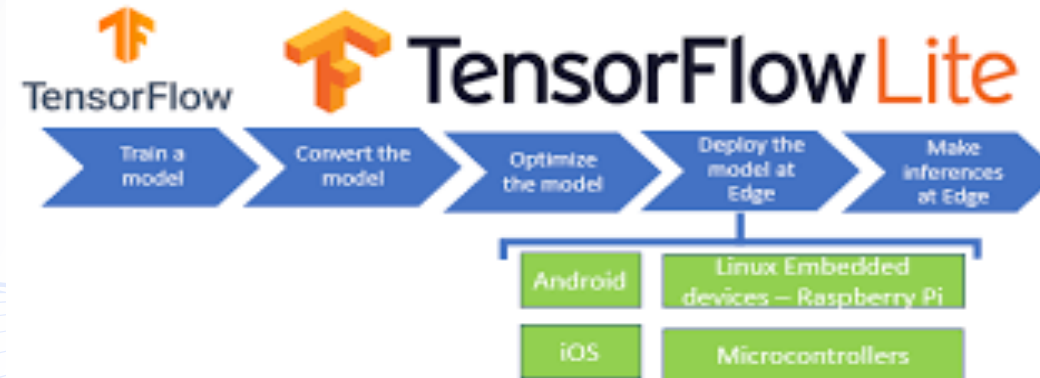
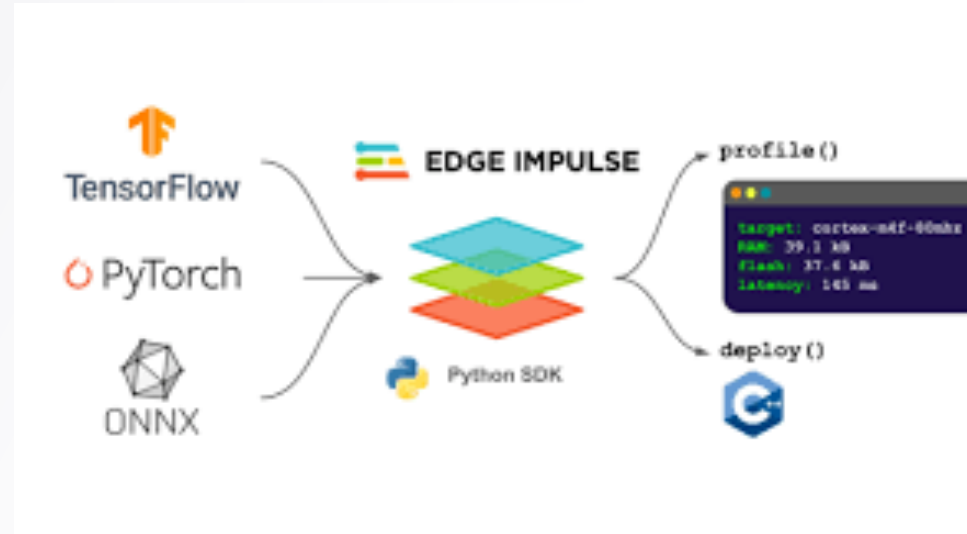
Tensorflow Lite

ARM CMSIS-NN

PyTorch Mobile

uTensor

Keras



Source : <https://resources.system-analysis.cadence.com/blog/tinyml-will-drive-more-advances-in-embedded-ai>



Microcontrollers – Bare Metal EV Board

Nordic

STM32

ESP32

Arduino

Sparkfun edge



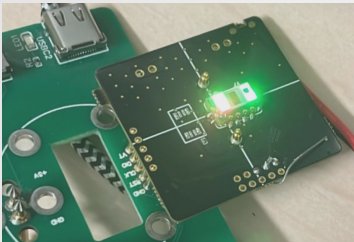
Source : <https://www.tensorflow.org/lite/microcontrollers>



Pipeline of TinyML Inference in Action



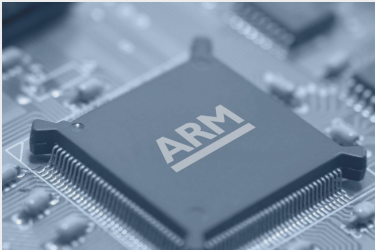
Sensor data



- heart rate →
- temperature →
- spo2 →
- accelerometer →
- gsr/eda →
- time →



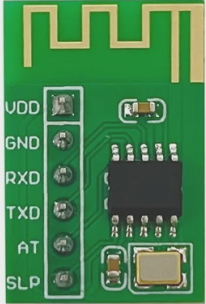
compute




-
-
-
-
-
-
-
-



communicate



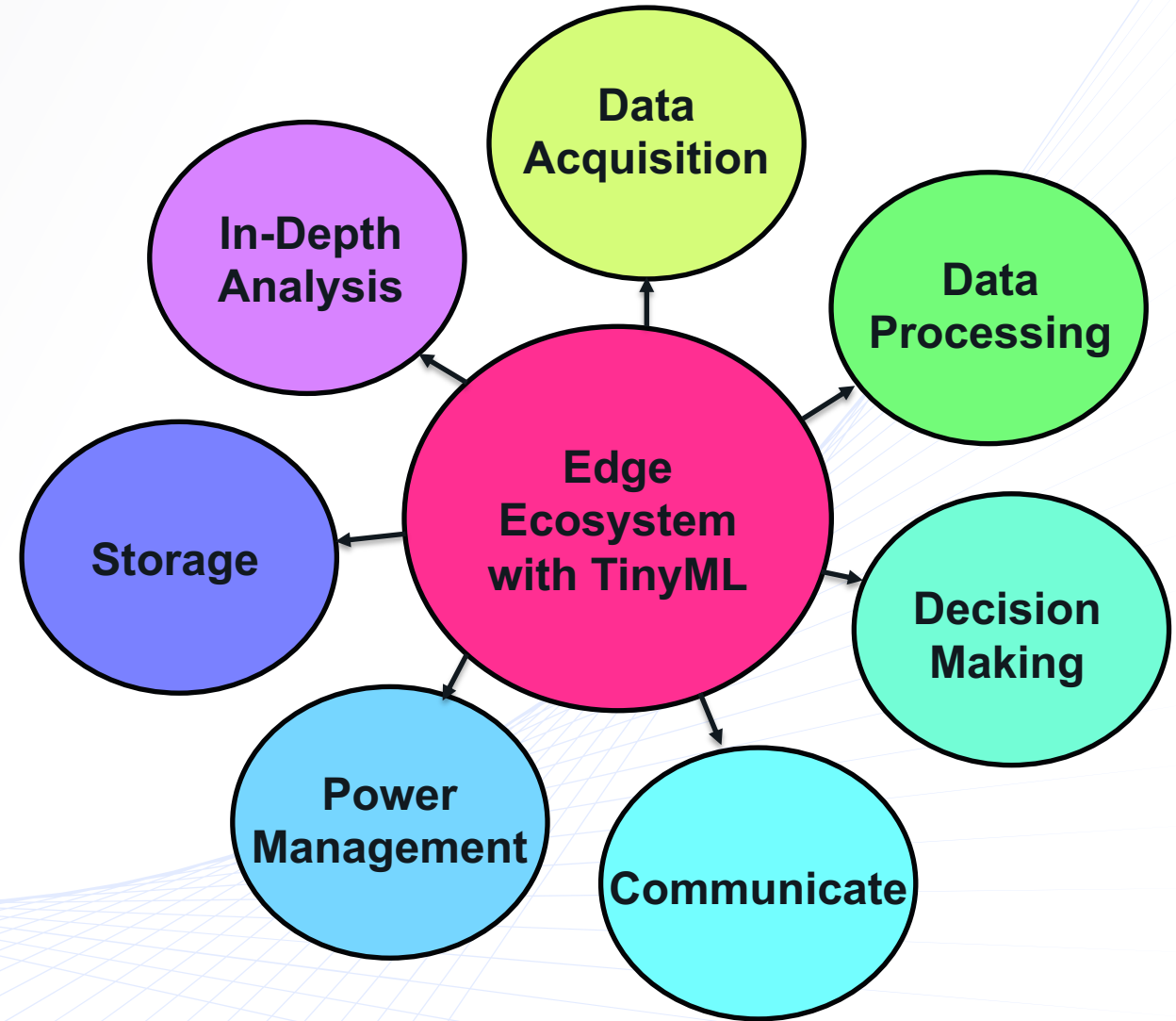
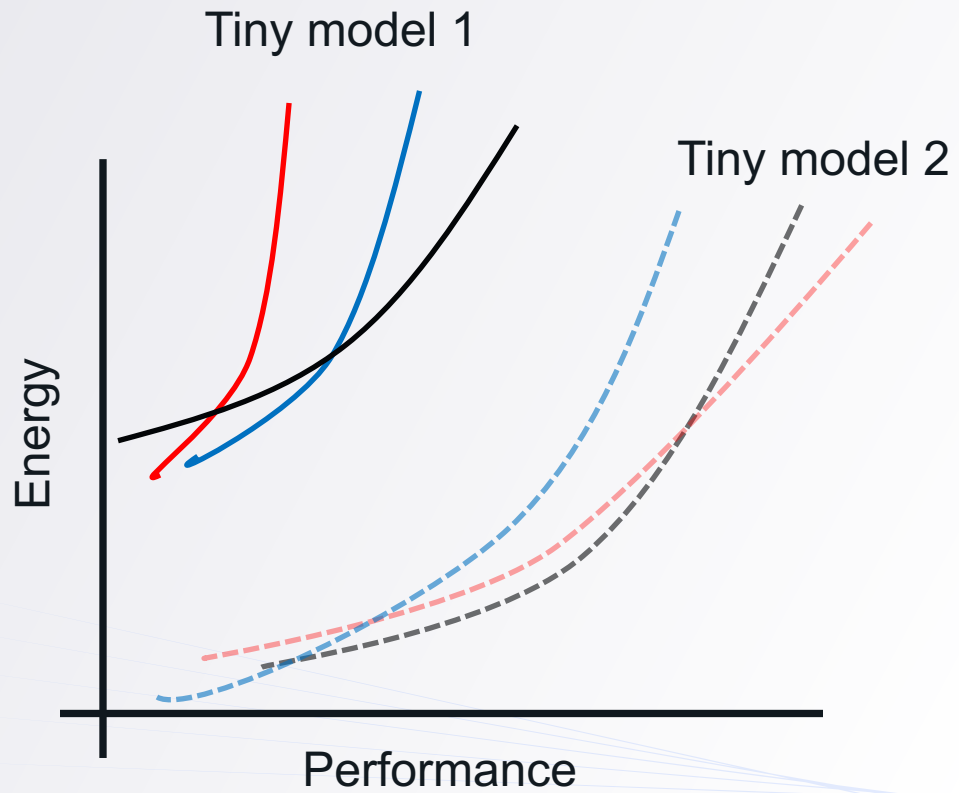
-
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storage



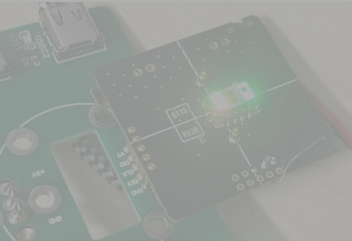
Pareto Optimal Curve Changes




Use Case #1: Stress Detection

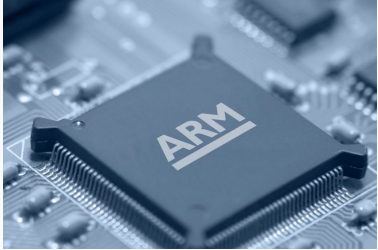
Trade-off between data computation, storage and communication

Sensor data




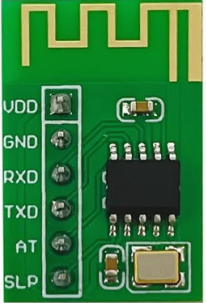
heart rate
temperature
spo2
accelerometer
gsr/eda
time

 **compute**




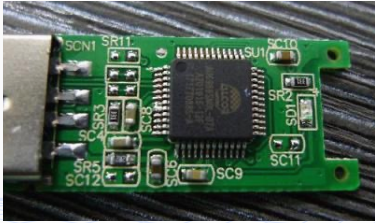
Five horizontal arrows pointing right and five vertical arrows pointing down.

 **communicate**



Five horizontal arrows pointing right.

 **storage**

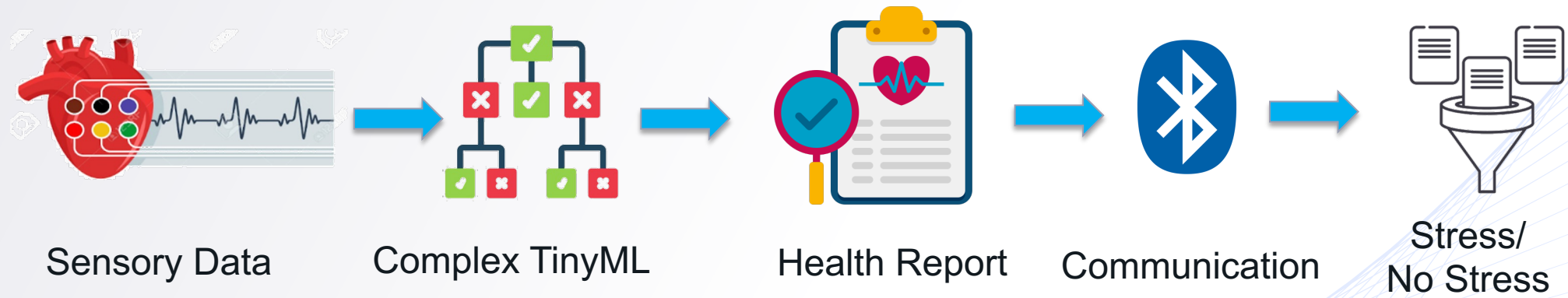


Optimal allocation of computation and communication in an IoT network

A Chopra, H Aydin, S Rafatirad, H Homayoun
ACM Transactions on Design Automation of Electronic Systems

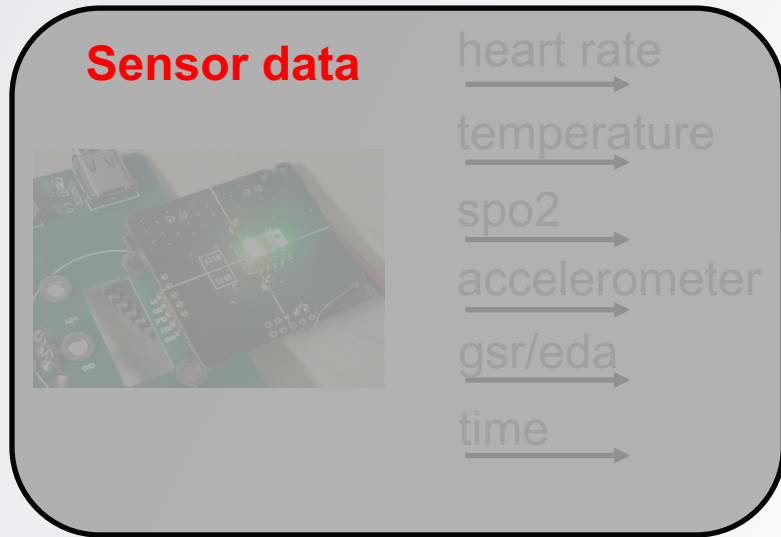


Use Case #1: Stress Detection




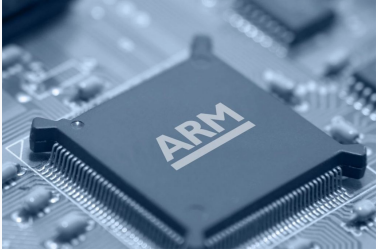
Use Case #2: Trade-off between data computation, storage and communication

Sensor data




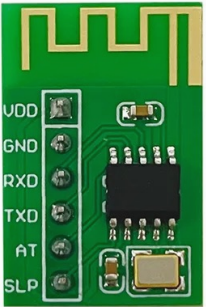
heart rate
temperature
spo2
accelerometer
gsr/eda
time

 **compute**





Five horizontal arrows pointing right and five vertical arrows pointing down.

 **communicate**

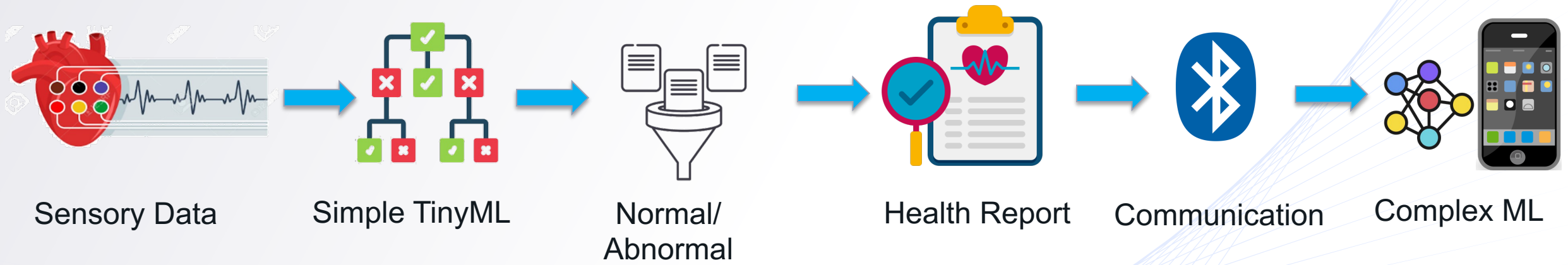


Five horizontal arrows pointing right.

 **storage**

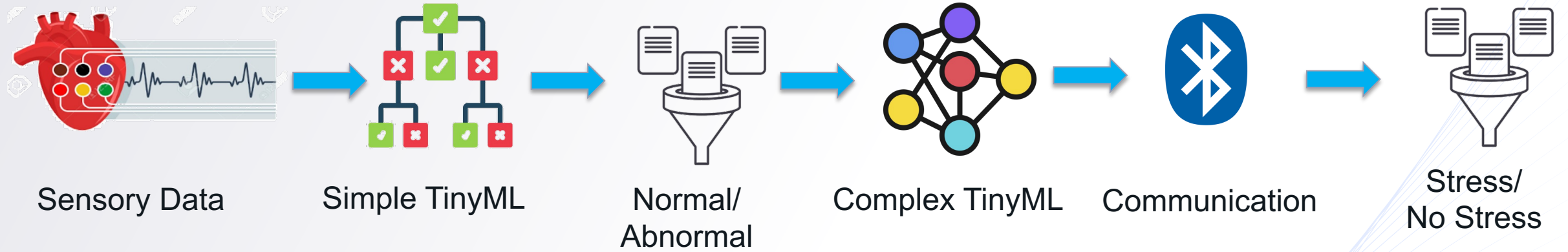


Use Case #2: Stress Detection



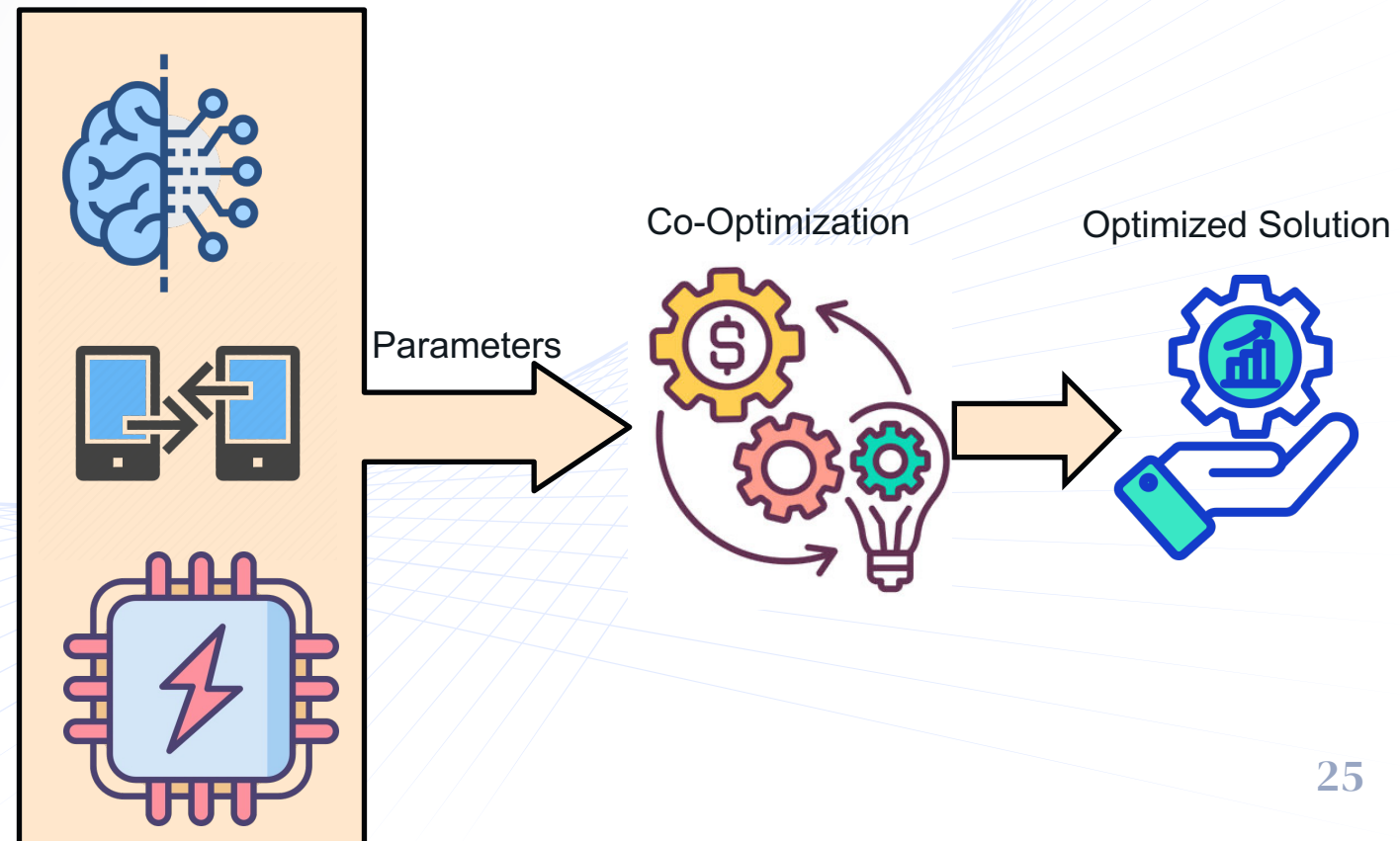
Use Case #3: Stress Detection

Adaptive Two-Stage TinyML on Edge



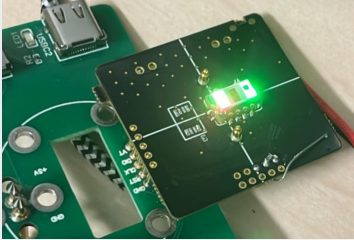
Parameters for Co-Optimization:

- Data rate
- TinyML model selection
- Processing candidate
- Communication overhead




Trade-off between data rate, data computation, storage and communication

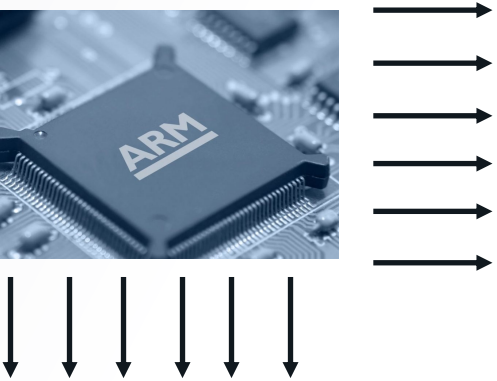

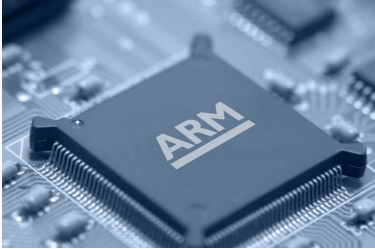
Sensor data





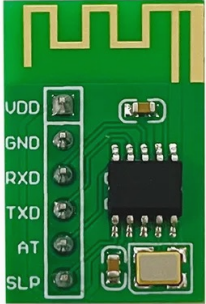
- heart rate →
- temperature →
- spo2 →
- accelerometer →
- gsr/eda →
- time →





compute



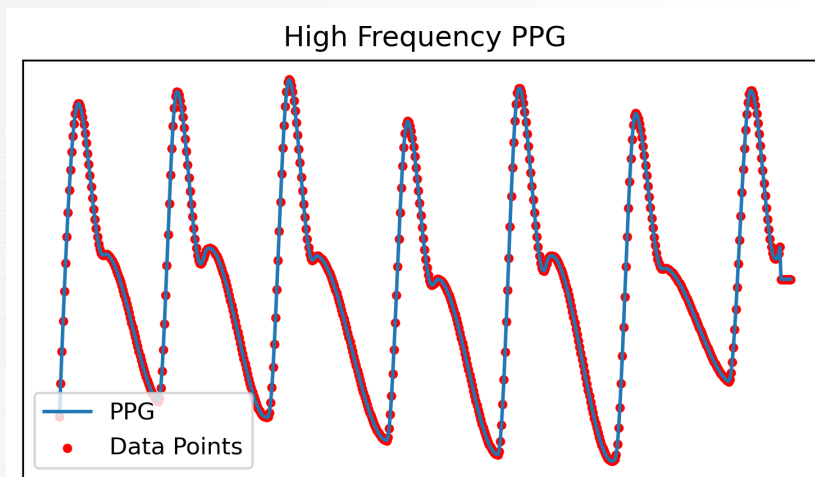
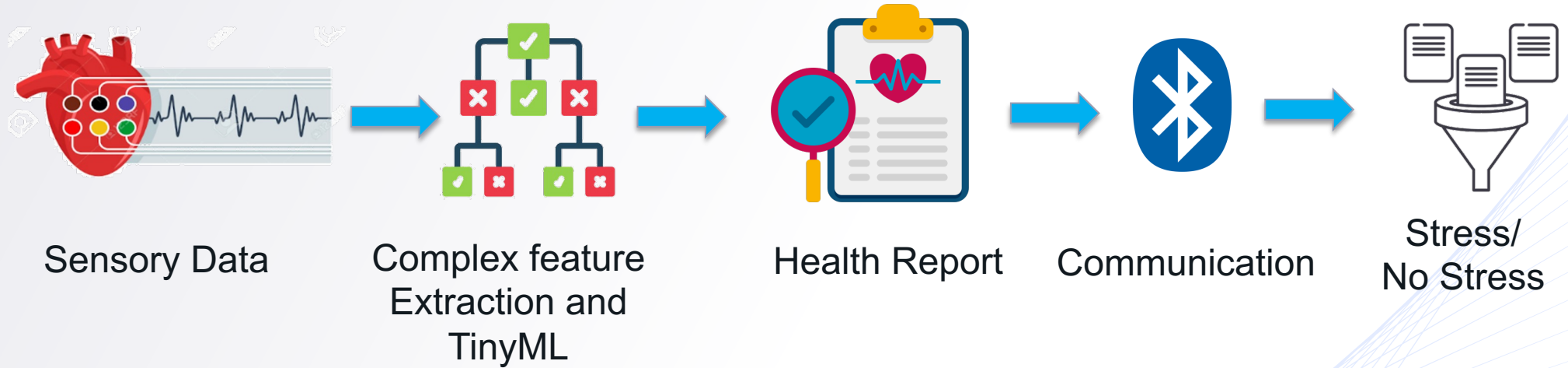
communicate



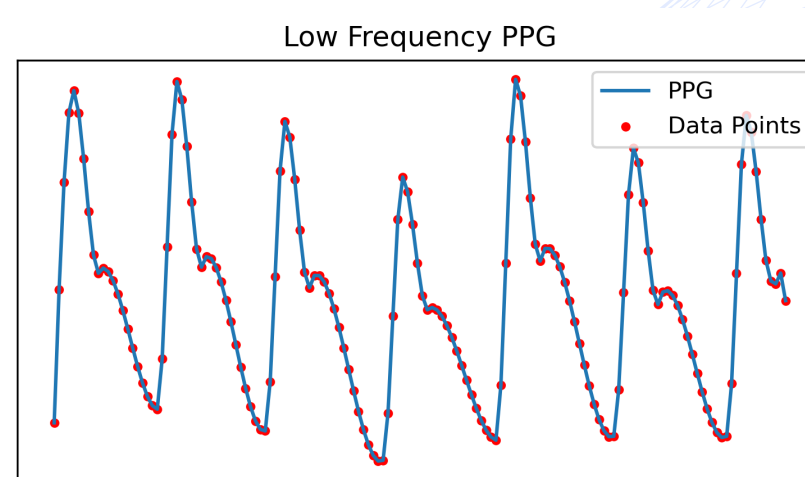
storage



Use Case #4: High data rate – complex time and frequency domain feature extraction



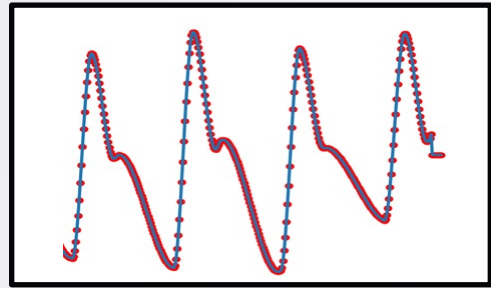
PPG data at 100 Hz



PPG data at 25 Hz

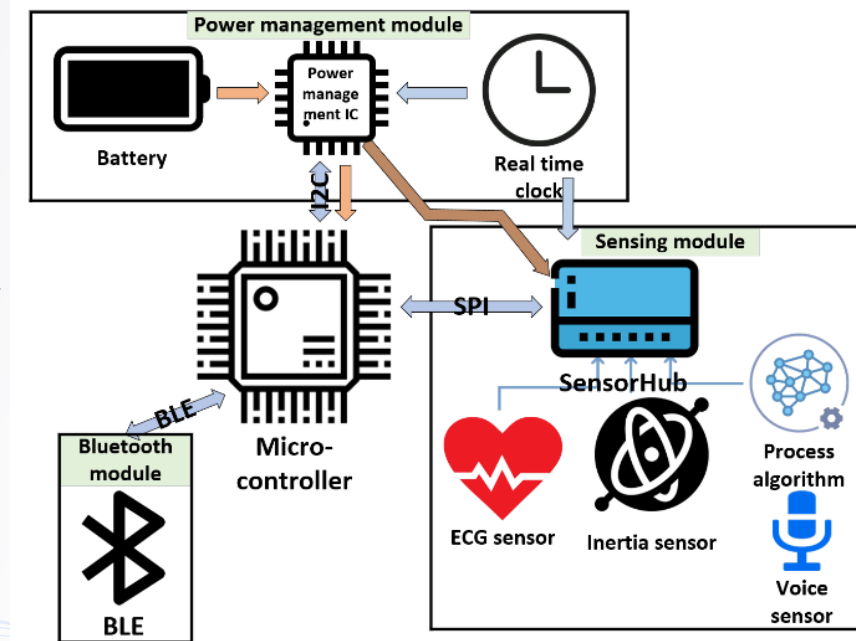


Example Study #1

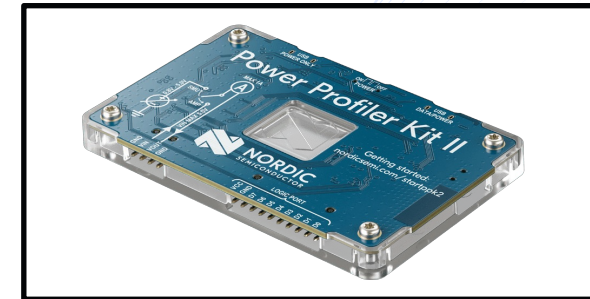


Data Management:
Frequency change, Data
compression, Noise
reduction and filtering,
Feature extraction, Data
augmentation

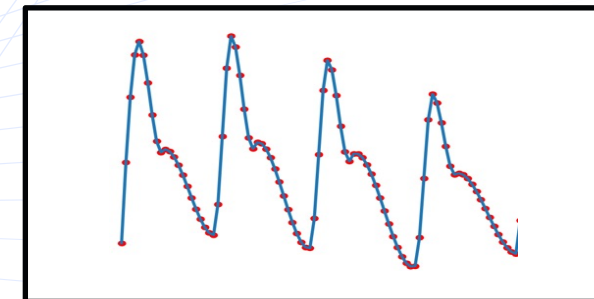
We-Be System



Power Profiler



Output Data

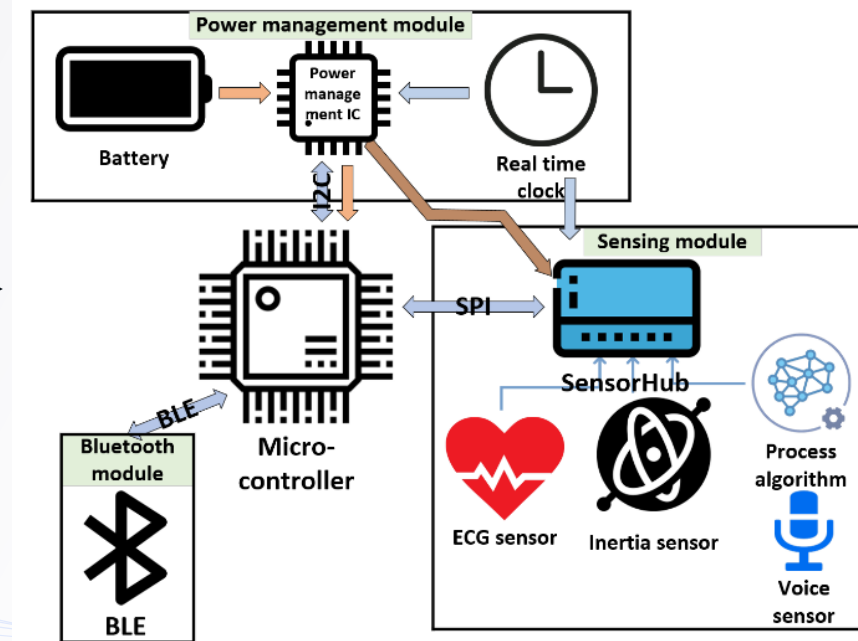


Example Study #2

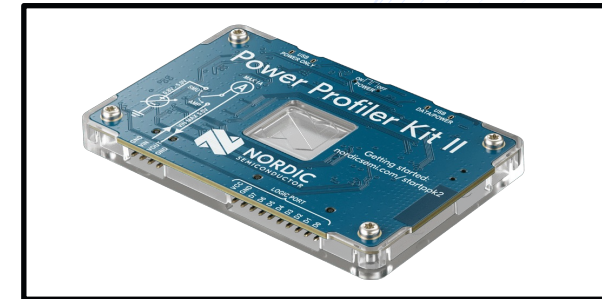
We-Be System



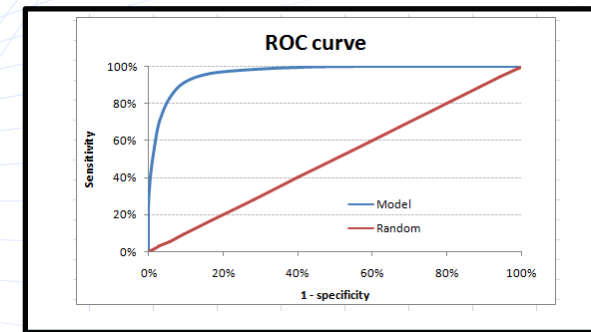
Machine learning algorithm



Power Profiler

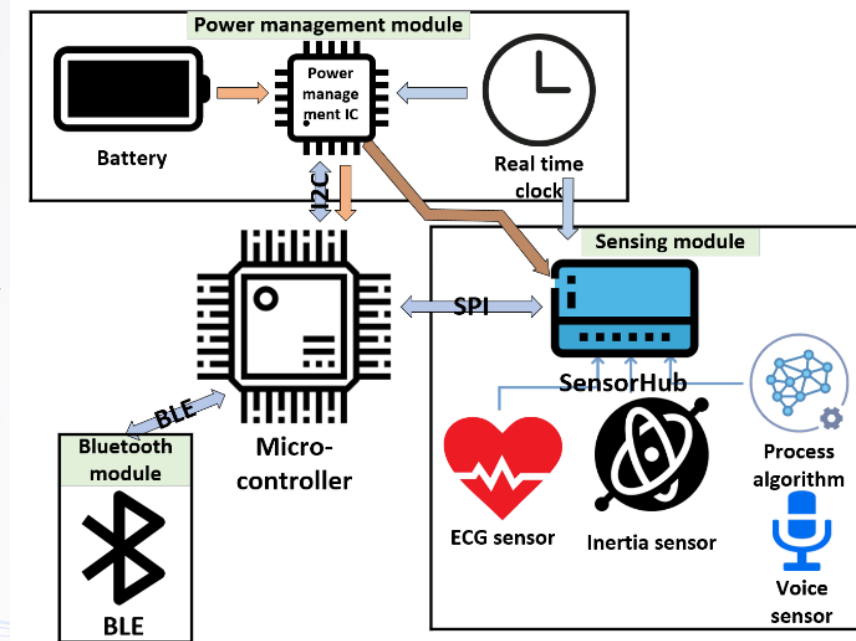


Evaluation Metrics

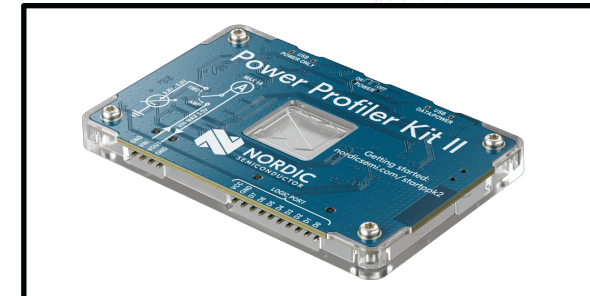


Example Study #3

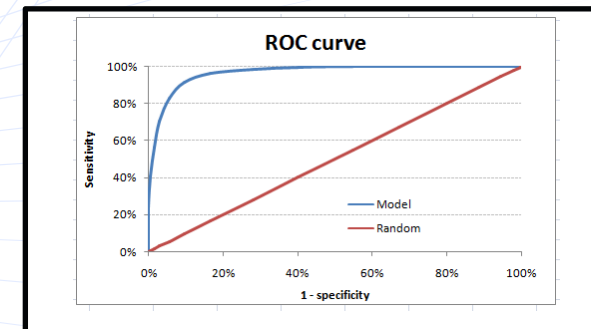
We-Be System



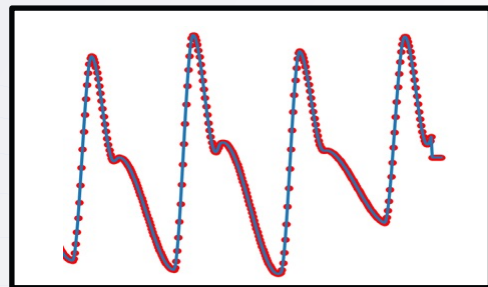
Power Profiler



Evaluation Metrics



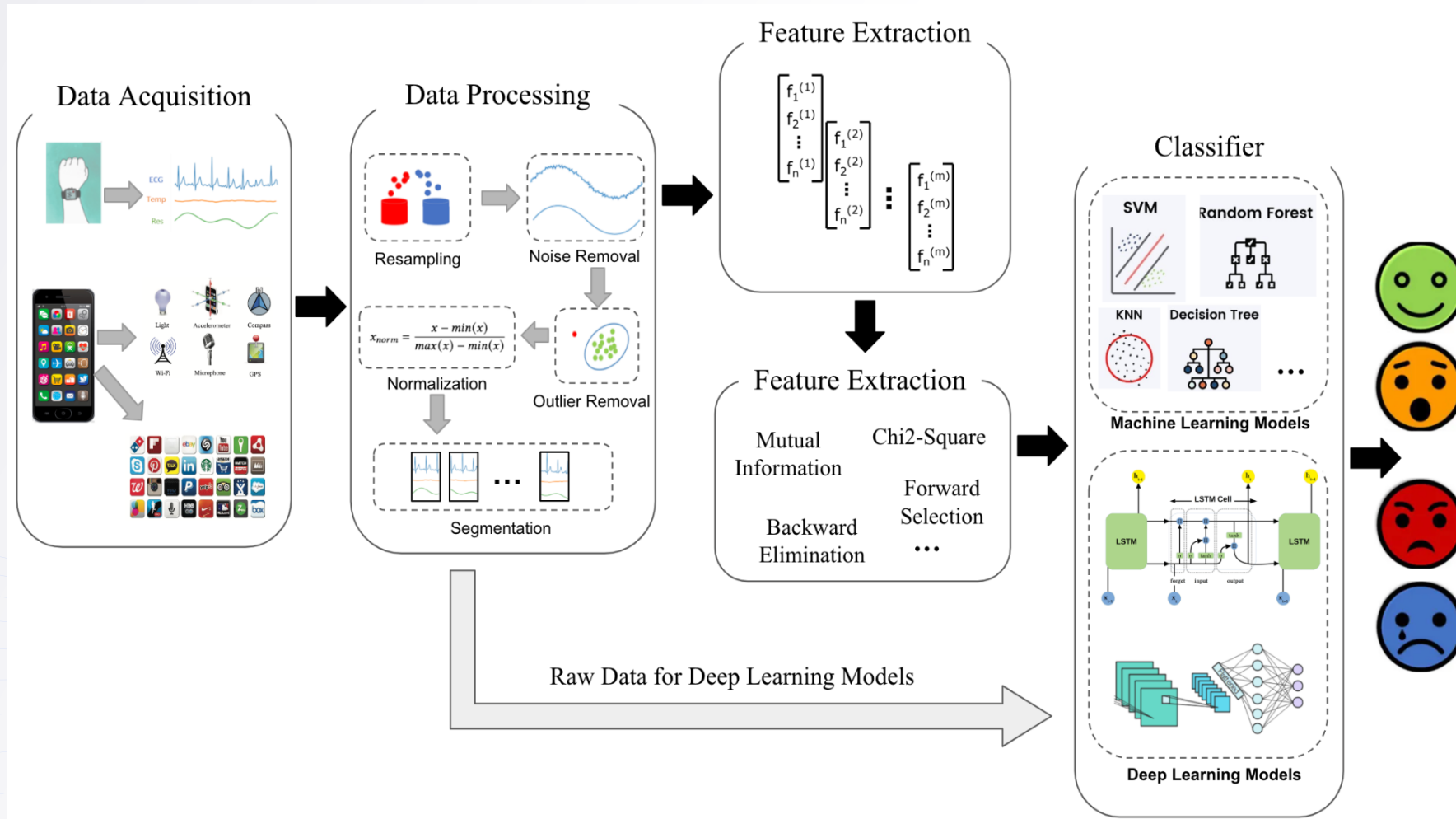
Machine learning algorithm



Data Management




Stress study example



Stress study example

Pre-processing – Feature extraction - Model

Computer  

Evaluation board  

We-Be band  

Algorithm	Inference	Accuracy	Compute Power	Peripheral Power
SVM	Offline	72.2%	-	-
RF		82.0%	-	-
SVM (TinyML)	Offline/In lab only	66.8%	17.3mW	54.7mW
RF(TinyML)		71.7%	28.9mW	
SVM (TinyML)	Real-time/Wearable	56.5%	14.2mW	38.6mW
RF(TinyML)		63.2%	22.1mW	



Deploying and Testing TinyML in We-Be



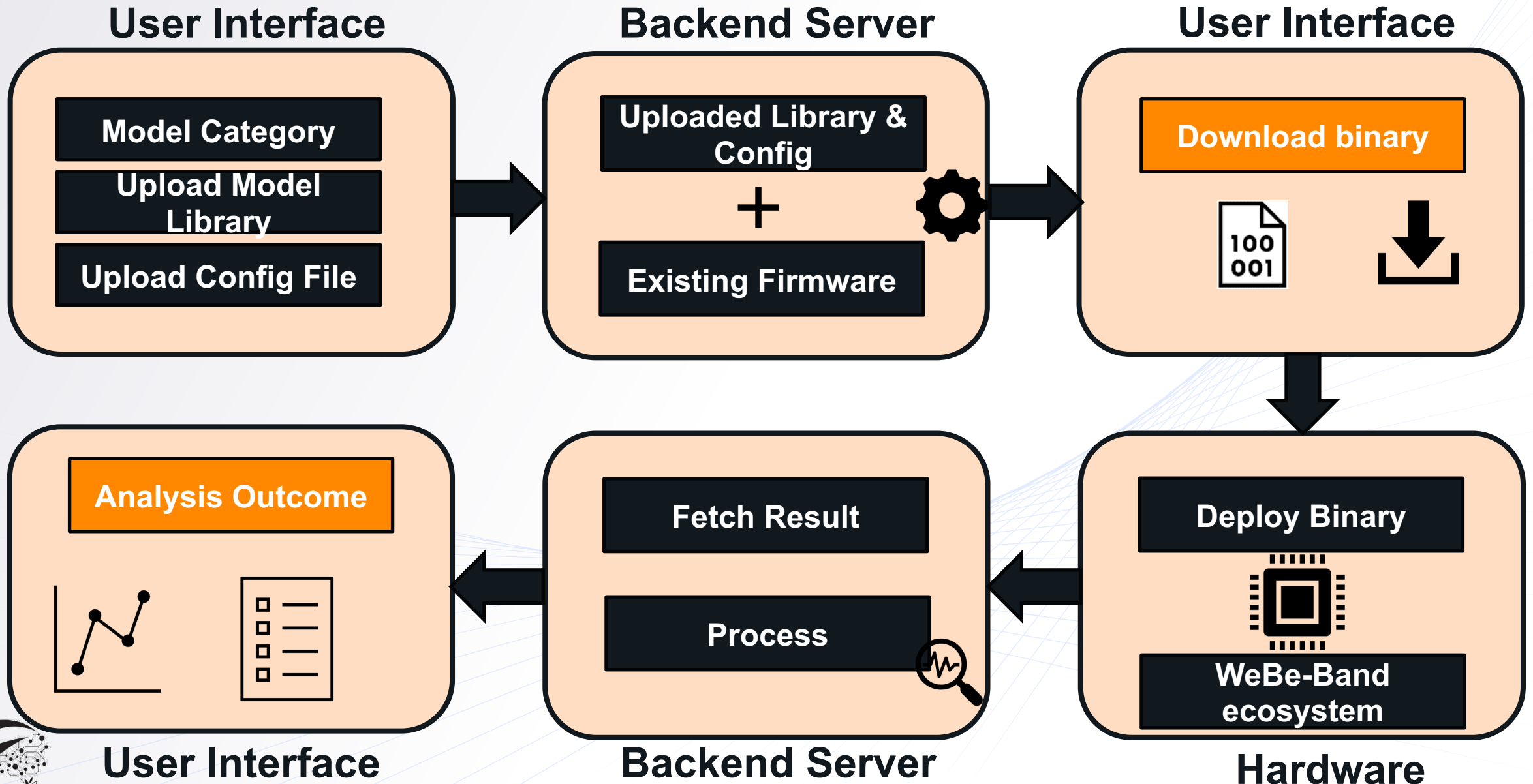
How we are doing it!

Smart Health Application
Ecosystem

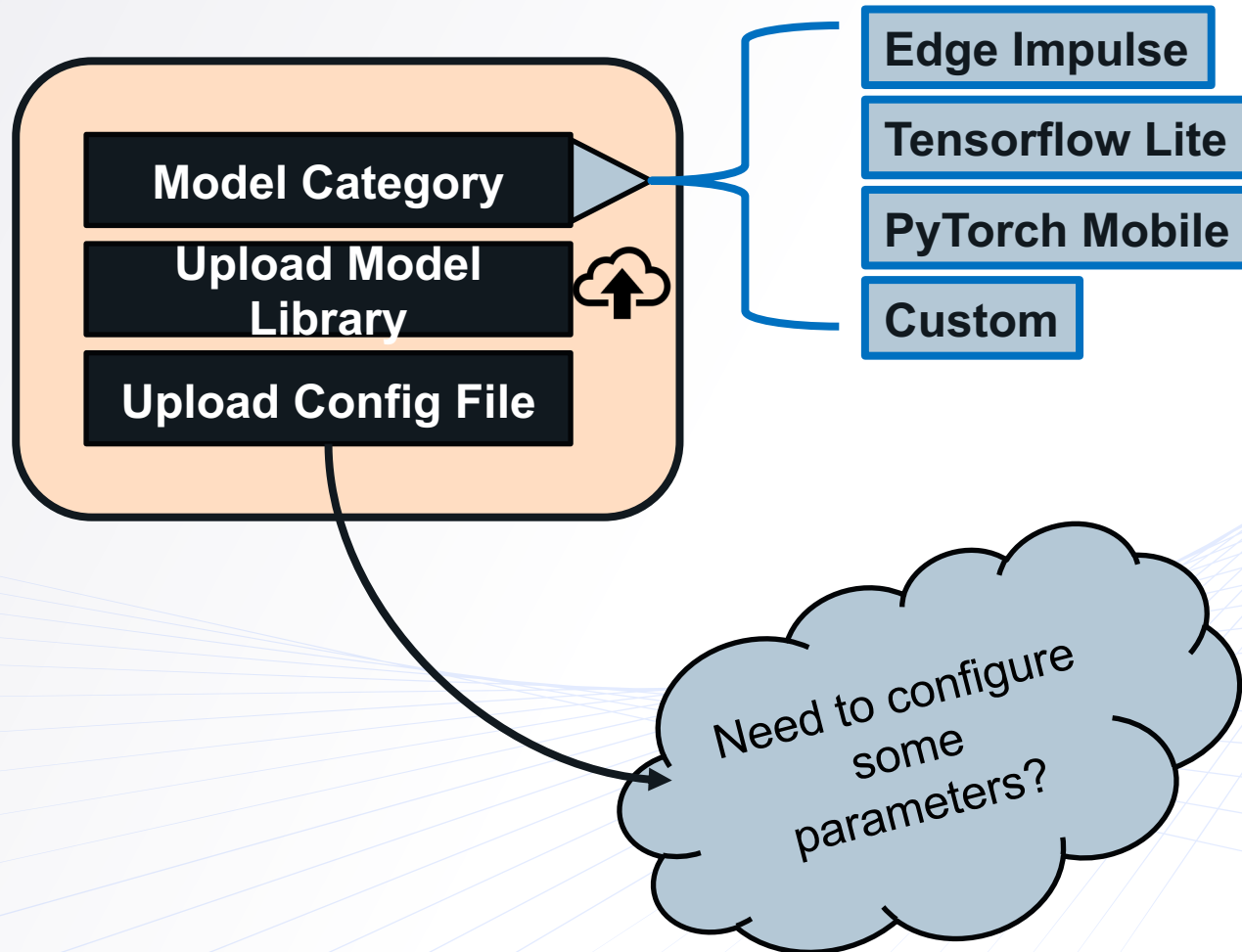
Analysis of different TinyML
models



Design: Overview



Design: UI



Outcome



Choose TinyML Model, Config

Deploy on the We-be Band

Analyze the performance and Power



Conclusion

Accelerating Innovation: AI has dramatically accelerated the pace of innovation in smart health

Addressing Research Needs: Critical gaps in current consumer-grade wearable devices for researchers to evaluate and enhance TinyML algorithms directly within the ecosystem

Understanding Trade-offs: Access to a full-stack system allows researchers to study intricate trade-offs, potentially influencing the choice of TinyML models

Enabling Deployment: Ongoing development of We-Be software component underscores our commitment to delivering a comprehensive, user-friendly platform for deploying TinyML

Looking Forward: We continue to innovate and expand We-Be, promising to further empower researchers with the tools necessary to push the boundaries in smart health



Other platforms

Azure Sphere

- Azure Sphere (MCU, Linux-OS)
- MT3620 chip (Cortex-A7, Cortex-M4F)
- Cloud-based security service
- ML on resource-constrained device
- Can process data locally
- Evolved with time, back in 2020, integration with Edge Impulse

Nordic Thingy: 53

- Cortex-M33
- Run model directly on hardware
- Connects with Edge Impulse
- Includes different integrated sensors
- In-built firmware to directly connect with Edge Impulse

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