

How Al is Transforming Health Tech

EDGEIMPULSE.COM

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Section 1 Industry Overview



Introduction

How AI is Transforming Health Tech

From creating more reliable cleanroom manufacturing to innovating new lifesaving medtech devices, AI is opening new growth and value to all parts of the health industry.

Al and machine learning are transforming healthcare from every angle: operations, clinical research, diagnostics, patient care, and healthcare delivery. Much of this transformation is happening all over the network with connected devices, smart medical equipment, factory monitoring systems, and data collection from disparate sources aggregated in-house for processing and analysis.

With advancements in chips, sensors, and software, there are now lots of opportunities to move more computing and analytical processing to any type of device across secure and closed networks.

How Healthtech companies are using AI with internal systems and smart devices

Healthcare companies are collecting more data, working with larger datasets, with access to more data inputs than ever before. Your company needs systems to manage everything from creating data with devices to collecting data from devices, third parties, and internal systems. Your company also needs a platform to build smart devices for your patients and your factories. You also need a way to analyze, catalog, and process this data in a standard way to boost efficiencies, enhance patient care, improve patient outcomes, and operate efficiently.

These include:

- Smarter connected devices, from medical equipment to hospital machines to wearable medical devices that collect data directly on the patient or from the patient's room in a hospital setting.
- Streamlining complex data collection and analysis driven by sources as disparate as wearable devices, clinical research, medical imagery, and patient-provided data
- Increased operational efficiency across the supply chain, from manufacturing to tracking to delivery.

Why Healthtech's data needs are different

Healthcare companies have rigorous requirements for data collection, data handling, and privacy compared to other organizations on their AI journey. Healthcare is governed by ethical requirements, governmental mandates, and patient safety regulations to ensure the safekeeping and accuracy of sensitive patient information.

Why edge computing combined with AI is a game changer for healthcare

Edge computing allows an individual device to handle and process data locally instead of sending it to the cloud or another network. This ensures access to the sensitive data is private, limited and controlled. Healthcare companies can use edge computing and edge AI, to deploy the principles of least privilege for data collection, data processing, and more to ensure data security and privacy.

Health companies need to design and deploy AI and machine learning for smart devices and systems locally and on devices like wearables and imaging machines to enhance patient care and maximize staff utilization. These AI models should be tailored to that device's unique characteristics and requirements to maximize security, design for low latency or bandwidth, minimize processing or power consumption needs or prioritize the privacy of the dataset.

Learn how health companies are collecting and analyzing data to improve patient outcomes and monitor ongoing health.



Section 2 Use Cases For Health



Increased health insights

Provide personalized health insights to the wearer through biometric sensor-based ML algorithms designed to provide real-time feedback and alerts.

More user-privacy

Process sensitive user data on-device and reduce the need to send raw data to a cloud environment, where it can be more easily exploited.

Always responsive

On device processing of data ensures that that monitoring and insights can be delivered constantly, even in low connectivity or bandwidth environments.

Build your smart health devices faster with Edge Impulse

Edge Impulse lets you deploy your data model to any device, on any processor, with any sensor, and in any network environment. Schedule a demo with us to learn more.

Edge Impulse can also assist with the entire data collection, labeling, and analysis process. Our platform gives you one place to consolidate the data you have collected, label the data, and build a model from your dataset.

Expert support

We are the leaders in embedded ML, with track records of working with top enterprises developing solutions across the wearables, industrial and consumer spaces.

Less engineering time

Speed up development timelines with the best-in-class embedded ML platform, designed to help you create productiongrade software in less than six months.

Open source, royalty-free

All Edge Impulse developed algorithms are licensed under Apache 2.0, without royalties. This means that you completely own your algorithms, and no royalties exist when it comes to deploying them.

Flexible deployment

Models developed in Edge Impulse can be deployed to any edge device, whether that is a MCU, processor, GPU or even a mobile device.

Data agnostic

Our platform allows enterprises to manage their sensor, audio and vision data regardless of how it is formatted and where it exists today. From data transformation to DSP, we can help you visualize and wrangle your data to unlock its potential.

Develop new skillsets

Build in-house embedded ML skills over time with Edge Impulse, which can be accessed as a low-to-no code tool to a Jupyter notebook which can be used to make API calls to the platform.

Blog Post

Getting the Pulse: Technical Insights Into Edge Impulse's New HR and HRV Blocks

Machine Learning



In digital health engineering, few metrics are as vital as heart rate (HR) and heart rate variability (HRV). These offer profound insights into health, and at Edge Impulse, we have made substantial strides in simplifying the measurement of HR and HRV for resource-constrained devices. In this exploration tailored for engineers in the digital health industry we'll dive deep into the technical aspects of Edge Impulse's HR and HRV features. This article will help you gain a comprehensive understanding of PPG heart rate estimates, HRV feature generation, embedded code for on-device inference, and more.

Demystifying HR and HRV

Before we delve into the intricacies of Edge Impulse's offerings, let's establish a foundational understanding of HR and HRV.

Heart rate (HR) interbeat intervals

The measurement and analysis of heart rate interbeat intervals (IBIs) are fundamental in the study of cardiovascular physiology and health. IBIs, also known as RR intervals, represent the time intervals between successive heartbeats, specifically the time elapsed between the R-peaks of consecutive QRS complexes on an electrocardiogram (ECG) waveform.

Heart rate variability (HRV)

is a measure of the variation in time between successive heartbeats. It goes beyond the measurement of the heart rate itself.

These variations offer insights into the balance between the sympathetic and parasympathetic branches of the autonomic nervous system of the autonomic nervous system, providing insights into various aspects of our health, including autonomic nervous system balance, cardiovascular health, stress levels, and fitness and recovery.

"A healthy heart is not a metronome"[1] — it exhibits complex patterns best described by mathematical chaos.

Real-world applications using HR/HRV features

Atrial fibrillation classification

Atrial fibrillation, a common cardiac arrhythmia affecting millions, can be detected using our HRV features extracted from PPG signals [2]. This approach offers diagnostic accuracy comparable to ECG-based methods, enhancing diagnostic accessibility for a broader population.

Blog Post



Atrial Fibrillation Graphs - Edge Impulse Studio

Stress detection

Psychological stress, affecting sympathovagal balance, is closely reflected in HRV metrics. This demonstrates that HRV can serve as an informative marker of the physiological effects of psychological stressors in healthy adult populations.



Edge Impulse Stress Detection project trained with HRV extracted features from 40k data samples

Sleep staging

Recent studies[3] have explored the use of HRV as a parameter for sleep staging. It offers a convenient, non-invasive, and cost-effective approach to monitoring sleep stages. While these results are obtained from HRV features alone, combining them with actigraphy and respiratory features can further enhance accuracy.

Empowering progress in digital health

Reduce R&D costs

Edge Impulse HR/HRV solutions leverage cutting-edge algorithms, eliminating the need for prolonged algorithm refinement. This streamlined approach significantly reduces research and development (R&D) investment, enabling accelerated product development.

Reliability

We deliver precise and dependable Interbeat Interval (IBI) measurements for HRV analysis, catering to a wide range of customer applications. This ensures that your digital health device consistently provides reliable results.

Large-scale clinical studies

Edge Impulse offers a robust infrastructure for expanding centralized and decentralized

clinical studies to encompass small and large cohorts of subjects. This scalability is vital for rigorous testing and validation, ensuring that your dataset is diverse and minimizes model biases.

Solution expertise

Our solution engineers possess extensive expertise in applying HRV data to edge AI projects in the digital health domain. You can tap into this wealth of knowledge to save time and gain insights from industry experts.

Hardware-optimized ML models

Our models are meticulously crafted to operate efficiently on resource-constrained edge devices. This guarantees that your digital health product remains cost-effective.

To discover how Edge Impulse HR/HRV can enhance your digital health project, please visit our **website** or reach out to our team. We are here to support your innovation and provide impactful health solutions that truly matter.

Edge Impulse's technical arsenal for HR and HRV

The suite of modules we provide for HR and HRV analysis encompasses feature generation libraries, on-device capabilities, a reference design, and strong expertise from our teams to leverage.

Edge Impulse HR/HRV features

For enterprise users, Edge Impulse offers libraries for HR and HRV feature generation, accessible both within the Edge Impulse Studio and on-device. Additionally, we provide blocks that facilitate training with raw PPG/ECG data within the Studio.



PPG/ECG to IBI Library

The first library we provide is called PPG-HR. It can efficiently and accurately detect heartbeats from either PPG or ECG signals, and then calculate the HR interbeat intervals (IBIs).



[4] - Illustration of deriving HRV data from ECG and PPG signals, (a) RR intervals in the ECG signal, and (b) PP intervals in the PPG signal. N.U.: Normalised units.

HRV feature extraction library

The output of the PPG-HR block is typically used as an input to the HRV extraction block. For situations where IBI data is already available, the HRV library can be run standalone, directly with IBI input.

In the time domain, you can extract metrics like AVNN, SDNN, rMMSD, pNN50, Mean HR, HR percentiles, IQR, HR slope, and rMMSD slope.

In the frequency domain, you can extract VLF/LF/HF values, energies, ratios and peaks, and boundary adaptation metrics.

The library also supports more advanced metrics like Sample Entropy, DFA, SD1, SD2, SD2/SD1 ratio, and circadian features.

Extensive resources

In addition, we also provide multiple Studio project examples and a full reference design to help our customers facilitate the understanding and the replication of advanced workflows. Edge Impulse's algorithms can handle either PPG or ECG inputs, optionally integrating accelerometer data for enhanced accuracy. We demonstrated how to apply crucial filtering mechanisms to clean the signal and excel in precise IBI and HR estimation. Finally, to improve the detection of HR peaks, we can add feedback and tracking mechanisms. Remarkably, all of this is achieved with minimal RAM usage, consuming just 1.6K of memory.

Our commitment to simplifying heart rate variability (HRV) measurement aligns with our dedication to granting access to expert knowledge and advanced algorithms. By utilizing Edge Impulse HR/HRV solutions, you can streamline your development process, benefiting from the expertise of industry leaders in the digital health sector.



Section 3

Getting To Market From Idea To Launch



Accelerate the Design of Health Monitoring Algorithms and Research with Edge Impulse

Artificial Intelligence, Embedded Devices, Machine Learning



Machine learning and artificial intelligence (AI)-based methods have made a qualitative leap in recent years as a result of new computing software hardware infrastructure and the development of large zettabyte-era databases. These technologies, which serve as the foundation for consumer devices such as smart wearables, smartwatches, smart rings, and smartphones, have resulted in incredible progress on our daily lives, and are poised to transform other areas of healthcare, including clinical research. Here are the ways that Edge Impulse and its trusted suite of ML tools integrates into this segment, and how you can leverage them to help accelerate and amplify your health solution deployments.

Digital biomarkers are the next goldmine for preventative health and wellness companies

Digital biomarkers are quantifiable, measurable indicators that can be collected using devices. They can allow preventive insights to indicate whether a person is healthy or not by measuring blood glucose level along with other biometric parameters like heart rate and pressure.

Increasingly diverse digital biomarkers datasets coming from wearables will enable a whole new generation of preventive healthcare in front of us. Therefore, there has been increased interest in clinical research towards applications that use machine learning models to predictively understand one's state.

Managing diverse datasets for model development

Technical teams face difficulties in managing and organizing digital biomarkers for model training, which is a crucial process of scaling up the data to train models. These problems can be solved by using a platform that has all these capabilities:

- Centralized cloud storage for AI training that is compatible with different data silos and file types
- Data labeling tools compatible with audio, visual, and sensor-based digital biomarkers
- An integrated algorithm development toolset with no need to go back-and forth between different applications
- Ability to build embedded models optimized for any hardware device

Edge Impulse's scalable approach to health ML engineering

Edge Impulse already works with companies in the health device space like Nowatch, Oura, SlateSafety, and Knowlabs on their full data engineering and machine learning algorithm development process.

We offer a platform approach for this process to ensure that data is labeled properly, and that algorithms are built against data being collected from gold standard tests to ensure accuracy. Furthermore, algorithms can be tested and improved over time, and even personalized. This is especially critical for health-related algorithms to detect conditions such as fatigue or stress levels where variations between physiology may exist.

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GETTING STARTED		-

Screenshot from the Edge Impulse patlform showing feature importance during the health algorithm development process

Some use cases Edge Impulse has enabled on devices without the need for cloud compute:

- Predictive heat exhaustion device for firefighters
- Sleep quality analysis and scoring using a wearable ring
- Accurate non-invasive glucose monitoring systems
- Stress monitoring and predictive warning systems
- Fall detection and safety warning devices

Edge Impulse silicon team

Apart from using the Edge Impulse platform for predictive model creation, Edge Impulse offers a hardware reference design as an infrastructure to scale research studies and product development. Our silicon design team works with our cutting-edge silicon partners and enterprise customers to ensure that the infrastructure is in place to speed up algorithm development time, design with use case computation needs, and decrease go-to-market timing of new health devices.

Talk to our team

With these tools, healthcare developers are able to implement features that offer a competitive advantage while saving time and money. <u>Let's discuss further</u> on how Edge Impulse enterprise platform can help you bring new human health-related machine learning models, use cases, and devices to market.



Section 4





Case Study Prevent Heat Exhaustion



SLATE SAFETY.

Prevent Heat Exhaustion

Can machine learning keep first responders safe when they're most at risk?

Cloud-based systems that monitor vital signs can keep first responders and industrial workers from getting injured or even dying on the job. But what happens when people "go dark," and can't be reached by the cloud? SlateSafety wondered if their awardwinning BAND V2 could deliver real-time alerts even without connectivity. In just 10 days, working with the vast amount of biometric data generated from the field, SlateSafety and the Edge Impulse team were able to zero in on key parameters and create an accurate, compact algorithm for predicting heat exhaustion. The new algorithm, which runs directly on existing hardware, can give the wearer real-time feedback on the risk of heat exhaustion, and enhances existing products by making safety at the edge a working reality.

Results

- An accurate and e cient ML algorithm, ready to run on SlateSafety's existing Nordic-based device
- A 10-day development timeline, enabled by Edge Impulse's Solutions Support Team and Edge ML platform
- Real-time situational awareness, to avoid overexertion injuries and fatalities, even in areas without connectivity



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Founded in 2016 as FireHUD, Atlanta-based SlateSafety is a technology company that provides easy-to-use, realtime group physiological monitoring to first responders and industrial workers. The SlateSafety BAND V2 withstands the toughest environments to provide always-aware safety monitoring.



Specialized biometric monitoring

SlateSafety is a niche technology supplier, meaning they do one thing very, very well. So well, in fact, that their flagship product, the BAND V2, was named a best invention of 2021 by Time magazine. SlateSafety BAND V2 is a specialized wearable that looks for signs of stress when people are dangerous doing work, in extreme environments, and at risk of overexertion. Worn on the arm, under personal protective equipment (PPE), the SlateSafety BAND was originally designed for firefighters, since prolonged exposure to high temperatures, while wearing heavy protective gear, and having to carry or lift heavy objects, can easily lead to heat stress, overexertion, and other life-threatening conditions. The US Fire Administration, the lead federal agency for fire-data collection, reports that sudden cardiac death (a condition that can be brought on by overexertion), has been the number-one cause of on-duty firefighter fatalities in the US since the 1990s and, in almost every year, has accounted for the single largest share of firefighter deaths in the year. Military personnel and industrial workers are often required to wear heavy PPE, too, and can be subject to the same risks of overexertion.

> Time magazine named SlateSafety's BAND one of the best inventions of 2021

We're aggregating sensor data to produce more useful results. With the Edge Impulse platform, we were able to find patterns in our data quickly, and develop a specialized algorithm tailored to our needs. As a startup we're always looking for quicker ways to free up time and tackle other problems that walk through the door.

Joe Boettcher Chief Development O cer, SlateSafety





How it works

Looking under the hood, the BAND V2 is a heat-tolerant, auto-recording device that provides valuable biometric data without taxing the wearer. As a lightweight arm band, it doesn't interfere with mobility and, because it's always on, with no buttons to press, there's no chance of the wearer forgetting to start the monitoring function once they slip it on. The device is equipped with a sensor that tracks heart rate. Based the sensor readings, SlateSafety on algorithms extrapolate other biometrics, such as core body temperature, calories burned per minute, steps per minute, and exertion. The algorithm then identifies trends and, if there's cause for concern, sends an alert to a designated person, such as the fire chief or troop commander, so a decision can be made on how to proceed.

Using heart rate and motion biometrics, SlateSafety can predict future body temperature and prevent heat exhaustion for personnel in the field

Each BAND V2 sends data to a web interface for real-time alerting.

Moving to the edge

The SlateSafety BAND was one of the first safety devices to send data to the cloud for processing and, as mentioned above, has been recognized for its innovation and ability to keep connected workers safe.

But people fighting fires aren't always within reach of the cloud. Depending on the situation, they can find themselves in remote areas, underground, or in other places where cloud connectivity is either too unreliable for e ective monitoring or simply unavailable. To protect workers wherever they're needed, SlateSafetv wondered if they could move the processing to the BAND V2 itself, for always-aware monitoring without connectivity.





Making the sensors smarter

Beyond adding more awareness to the device itself, SlateSafety was also interested in adding predictive capabilities to their algorithms, using machine learning. It was helpful to know current core temperature readings, but it was even more useful to know what those readings were likely to become in the next five to ten minutes, so preventive measures, such as pulling someone out of the field, could be taken before the worst happened.

SlateSafety's new ML algorithm, which took only 10 days to develop, runs on their existing Nordic-based device and is available as an overthe-air update

Edge Impulse made it possible

Edge Impulse studio, designed to help developers and enterprises get higher-level insights from their sensor data, enabled SlateSafety to develop more advanced ondevice monitoring and prevention of heat exhaustion.

SlateSafety's developers were able to quickly and easily build ML and deeplearning models utilizing Edge Impulse's platform.

Perhaps the most impressive part of the project is that they were able to do all this in just 10 days, start to finish.

Blog Post



Using data they'd already collected

Machine learning begins with data, since the better the data you use to train the algorithm, the better your results. The Edge Impulse platform helped SlateSafety sift through their data, and the EON. Tuner helped them identify the machine learning pipeline that best suited their use case and dataset. Thanks to Edge Impulse, SlateSafety was able to rapidly simplify the problem by narrowing the feature set for training to just three parameters: heart rate, core body temperature, and core exertion.



A dramatically faster development timeline

Working with the Edge Impulse platform and the Edge Impulse's Solutions Support Team, SlateSafety was able to save untold hours of development time. SlateSafety prepared and analyzed the vast amount of data they had already collected and using the EON Tuner rapidly found the optimal solution in just 10 days. To perform end-toend optimizations, from the digital-signal processing (DSP) algorithm to the machinelearning model, while keeping the latency and memory requirements of their target device in mind, the team used the EON Tuner. SlateSafety was able to quickly identify the ideal trade-o between the di erent pre-processing and neural-network optimal architectures and to achieve performance, on their device. This kind of optimization is usually only done by data scientists, using complex model-training systems and codebases. With the EON Tuner everyone has now access to the same level of expertise.

Using the hardware they already had

Having trained their project on the three features, the next challenge was to create source code that could run on SlateSafety BAND's existing microcontroller. Memory is one of the scarcest resources on Using the EON Compiler, SlateSafety was able to create an algorithm that was so compact it could run in the existing design without changes. There was no need to upgrade the processor or add memory, so SlateSafety could introduce the new, predictive capabilities without having to go through a hardware redesign. The Edge Impulse development environment also includes a custom deployment block, which automates new model generation and makes it possible to pipe the new algorithm into SlateSafety's own CI/CD flow, for quick testing and deployment.

EON Compiler for a tiny model

Typical ML runtimes use a generic interpreter to load the model at runtime. This tends to be a more memory-intensive approach, which can be di cult to deploy in embedded systems. The EON Compiler produces a neural network that uses, on average, 25 to 55% less RAM, and up to 35% less flash, while retaining the same inference speed (latency) and accuracy, when compared to an uncompiled model using TensorFlow Lite for Microcontrollers.



New capabilities for existing devices

Another benefit of developing such compact algorithms is that SlateSafety can send new functionality to BANDS V2 already deployed in the field, as over-the-air (OTA) updates. This increases the lifespan and utility of existing devices, making the initial investment in technology that much more valuable. The ability to send OTA updates for new algorithms means SlateSafety can introduce new capabilities as soon as they're ready, without sending personnel into the field or issuing end-of-life announcements for their devices.

Training output		·		
Model	Model version: ⑦	Quantized (int8) 👻		
Last training performance (validation set)				
Loss 1,204.55				
On-device performance ③				
INFERENCING TIME	PEAK RAM USAGE 1.4K	FLASH USAGE 9.6K		

Ongoing evolution

What's more, since SlateSafety already has such an extensive amount of collected data, and can quickly identify and extract new features for ML training, they can easily explore new, preventionfirst approaches that will provide even more advanced protection and help save further lives.



Learn more:

Edge Impulse for data-driven engineering

Edge Impulse is the fastest growing development platform for edge machine learning, used by thousands of enterprises across 55,000+ ML projects worldwide. We are on a mission to enable the ultimate development experience for machine learning on edge devices for sensors, audio, and computer vision, at scale. From getting started in under five minutes to MLOps in production, we enable the development of highly optimized ML models deployable to a wide range of hardware from MCUs to GPUs.

To learn more visit **www.edgeimpulse.com**

About SlateSafety

Atlanta-based SlateSafety is a technology company that provides easy-to-use, realtime group physiological monitoring to first responders, the military, and industrial workers. SlateSafety aims to make jobs safer with rugged, reliable. and revolutionary connected safety technology. SlateSafety has received funding from the National Science Foundation, the National Institute of Standards and Technology, as well as the US Air Force and Army to accelerate the development of its IoT platform.

To learn more visit **www.slatesafety.com**

Section 5

About Edge Impulse



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Learn More





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