ON-DEVICE HUMAN ACTIVITY RECOGNITION "CONTEXTUAL SIGNALING" TECHNOLOGY

White Paper

VirtualBeam Inc.
San Francisco, California, USA
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VB-WP-HAR-CS-102516.04

Novel Algorithms Lead to Smarter and Savvier Devices

VirtualBeam, Inc. is a Silicon Valley technology company that builds systems software products for smart, interconnected, sensor-rich mobile devices. We have benefited from more powerful processors in smaller form factors each year, as Moore predicted it decades ago. Advancements in hardware design in terms of performance, power and size, has led to improved application processors, multi-sensors and SoC features. Consumer electronic devices are so resource rich in terms of memory, computation and communications that they can now run a full-fledged operating system and execute billions of instructions per second.

Whether for consumer electronics, medical or industrial markets, demand for smarter and savvier sensor-rich personal devices is growing. Personal devices find themselves in close proximity to the end user, and usually carried by the user, worn, or attached to the body.

Smart devices, always-on connectivity, and on-demand subscription service models, where number crunching and data analytics is performed in the cloud "only when necessary" will become de facto mode of operations for human users. Smarter and savvier means smart software that solves real problems, make decisions intelligently and on-time, and autonomously. Such devices reduce the load on Cloud computing and on the networking infrastructure. They also improve security and privacy. On-device computing reduces the current mobile cost structure by reshuffling the layers in the mobility value [supply] chain.

VirtualBeam has embarked on a new growth trajectory by focusing exclusively on enhancement or replacement of existing software solutions that connect people to smart HAR (Human Activity Recognition) data. Our software engines are the fastest (sub-second) and most accurate (16 metrics delivered vs. one by all other competitors) in the industry in processing data, and capable of on-device or on-cloud data processing. VirtualBeam offers reliable options to existing product solutions that deliver less than they promise.
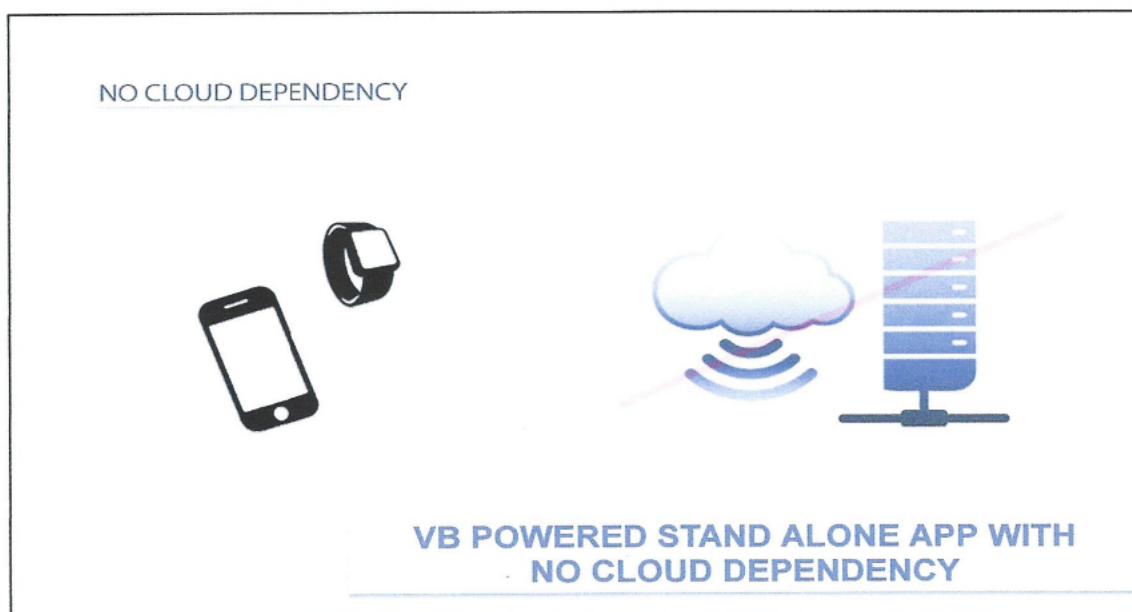
The VirtualBeam software platform is easy to use to advance a balanced and healthier lifestyle through unique and disruptive engines that allow measuring how activities affect wellness. The software predicts the range of health and fitness monitoring that a human body requires, custom-made to meet user needs.

Compatible with Google Android, iPhone iOS, and binary compatible to other embedded systems, our software can also easily integrate into existing setups and applications to build new ones, and complement, enhance or replace existing software on smart-watches, smart-phones, smart-wristbands and other smart devices with improved technology.

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This paper will introduce you to Human Activity Recognition (VB-HAR) technology developed at VirtualBeam. VB-HAR is a composite of software components with novel and complex algorithms that gives the device a better sense of movement in time and space. Processing of sensor data happens directly and only on the device. The device can then recognize natural body movements, active and inactive patterns, in real time. Smart algorithms and support libraries will signal the client software in real-time when the end user walks, runs, sits, turns, rests, rises, falls, ... and several other natural movements and activity patterns.

Similar to voice recognition software that analyzes input from an audio sensor (microphone) inside , the Human Activity Recognition software can analyze input from motion sensors (among others) to signal natural body movements, human activities and rest patterns, among other.
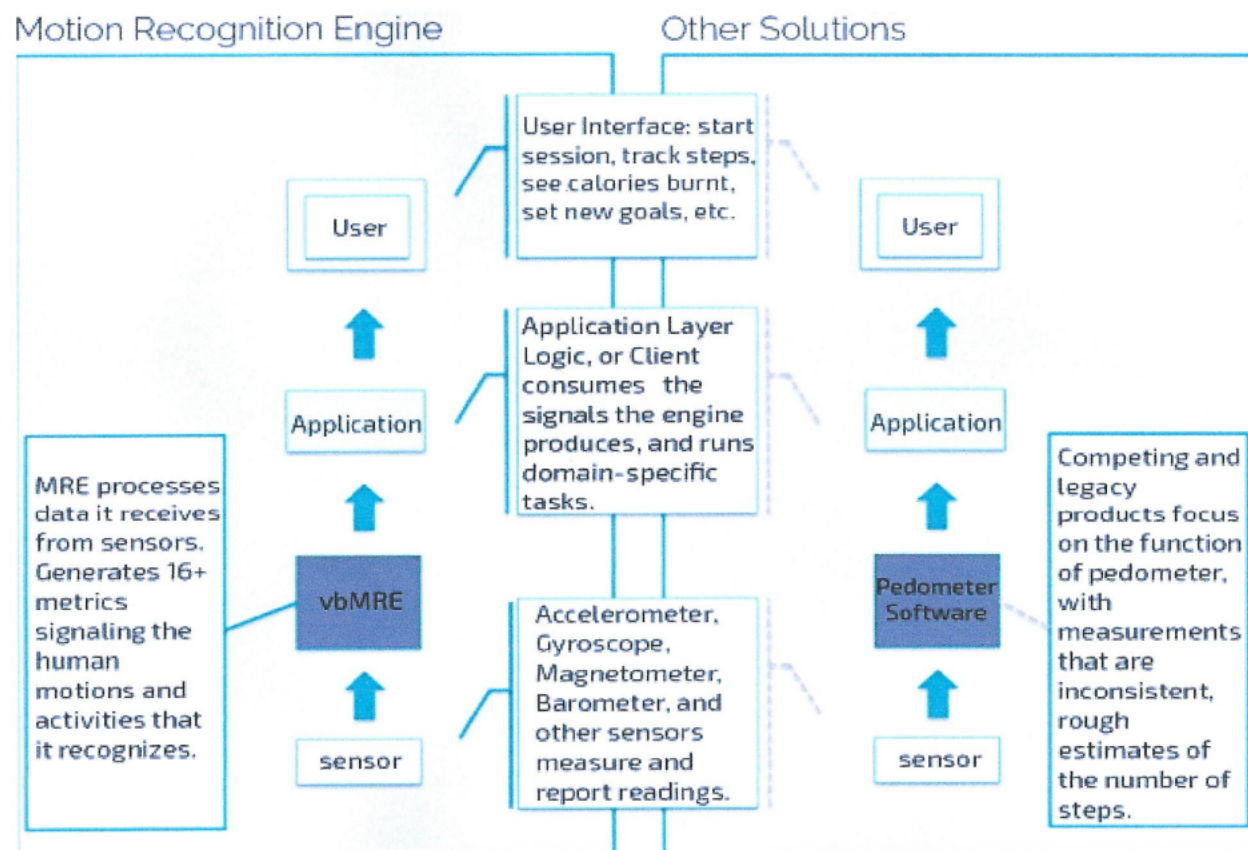
On-device processing is key for sensor rich platforms where every sensor type can generate a relatively high volume of data at a different frequency and resolution. Our software provides the ability to process sensor data directly on the mobile device and with HAR algorithms that terminate quickly, transforming the raw sensor data into meaningful information and context that the client application or service can process. On-device processing is pre-requisite for use cases and applications that have hard real-time response requirements and cannot afford the round trip delay inherited in cloud computing (or the transfer of sensor data over wire).

NO CLOUD DEPENDENCY

VB POWERED STAND ALONE APP WITH NO CLOUD DEPENDENCY

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VIRTUALBEAM®

Another benefit of our software/service is in reducing infrastructure utilization and cost as the smarter device can now make mission critical decisions and conclusions autonomously. The load can be distributed among billions of "smart" edge-devices where problems are solved collectively and in collaboration through smart signaling of context.

Cloud computing still plays an important role, used effectively for the user and device authentication, but inter-device signaling is more about transfer of "knowledge" using short and meaningful messages. We call this "context-signaling".

"Activity Recognition" software requires at a minimum, a relatively inexpensive board with motion sensors and a micro controller and a network connection to signal findings. Minimum sensor hardware requirements for VB HAR is an accelerometer and gyroscope combo. The software can add value to many products, from virtual-, augmented-, and mixed-reality devices, to smart headsets, to efficient tracking of carry-on devices and containers with precious goods. With the engine, devices become self-aware of how they

Motion Recognition Engine   Other Solutions

User Interface: start session, track steps, see calories burnt, set new goals, etc.

User

Application Layer Logic, or Client consumes the signals the engine produces, and runs domain-specific tasks.

Application

MRE processes data it receives from sensors. Generates 16+ metrics signaling the human motions and activities that it recognizes.

vbMRE

Accelerometer, Gyroscope, Magnetometer, Barometer, and other sensors measure and report readings.

sensor

User

Application

Pedometer Software

Competing and legacy products focus on the function of pedometer, with measurements that are inconsistent, rough estimates of the number of steps.

sensor

are being carried and can record or report patterns or incidents.

***VirtualBeam MRE (left) transforms raw sensor data into messages
that applications can process***

At the core of the VB-HAR platform runs the "motion recognition engine" (vbMRE), a featherweight software bundle which processes the data that accelerometers, gyroscopes and other sensors produce in-line and on-device (e.g., x, y, z readings from accelerometer at 20-Hz) to generate signals that qualify and quantify a range human activities and in-activities . The motion recognition engine software package, includes a "Sensor Adaptation Layer" that enables the engine to talk to different sensor types with different frequencies and resolution.

VB-HAR and vbMRE have been tested on a diverse family of boards powered by processors and micro-controllers of ARM, Intel, STM, and Arduino with inertial sensors manufactured by InvenSense, ST Micro, and Bosch. Benchmarks show that VB-HAR and vbMRE have deterministic and predictive behavior across all platforms. A flexible declarative programming interface allows this featherweight and modular software platform to readily integrate with a larger code base such as a mobile location based wellness services or in-hospital patient monitoring medical application. For higher level analytics, the VB-HAR platform provides interfaces to obtain non-motion sensor data allowing the fusion of environment and bio-sensor data.

On-device human activity recognition software requires that a complete set of algorithms that process sensor data fit and run on the edge device, with perhaps an inexpensive micro controller and low end motion sensor. Consider a smart shoe, headset, headband or other consumer device, with a 6-axis gyroscope/accelerometer combo chipset generating signals in real-time to a phone or watch to display "Actigraphs" - Speed and Accuracy is key for some applications while some can tolerate higher latency.

On-device human activity recognition, enables the delivery of thousands of new applications and services to IoT, Wearables, medical, industrial, adhesive, virtual reality and carry-on devices and containers. Recognition happens fast and is accurate. Tests conducted by major brands such as SONY and SAMSUNG identified our motion recognition engine as the fastest and most accurate in the world.

A nurse-station computer in hospital or remote can receive health related messages, with activity and sleep/rest context in real-time. Messages can be sent by VB HAR that runs on a smart medical wristband the patients wear, a smart adhesive band-aid, a smart piece of clothing or other. Feedback and instructions are sent back to the device based on observed active or non-active patterns along readings of bio and vital signs!
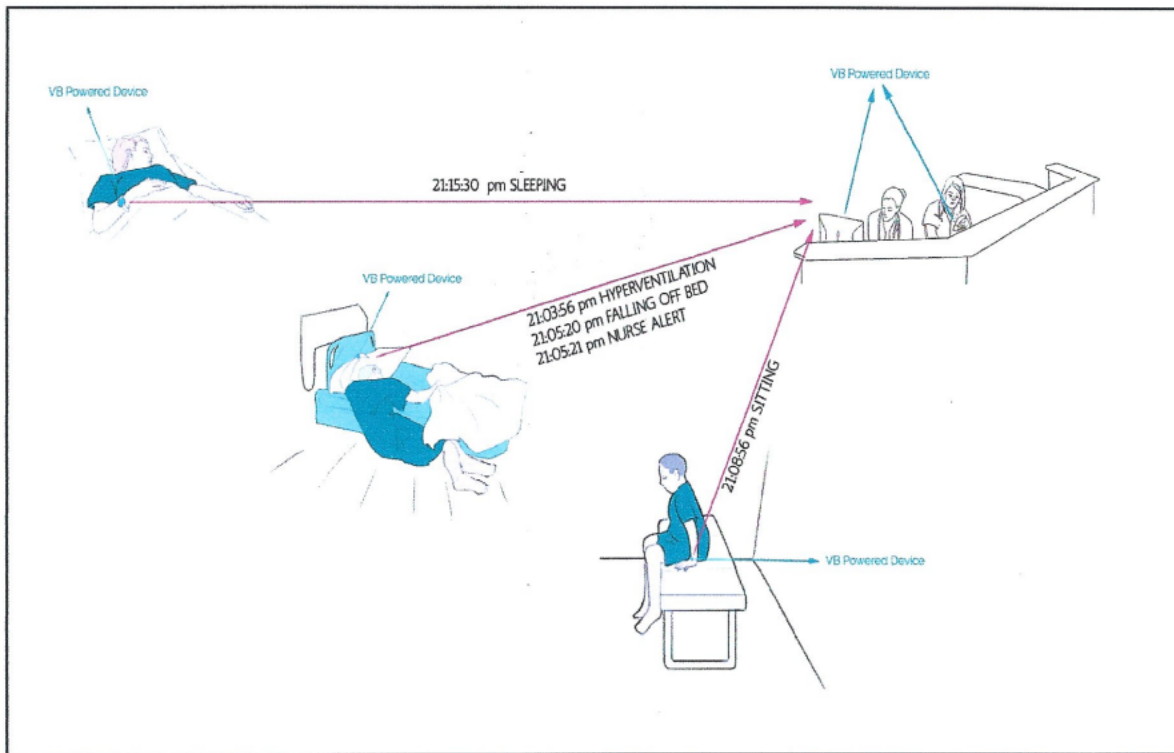
Smarter, savvier devices are possible only with improved, and better algorithms! Fast does not necessarily mean smart! But to interact with or mimic another human or device, a device needs to be able to establish some form of awareness, or "being" (through software).
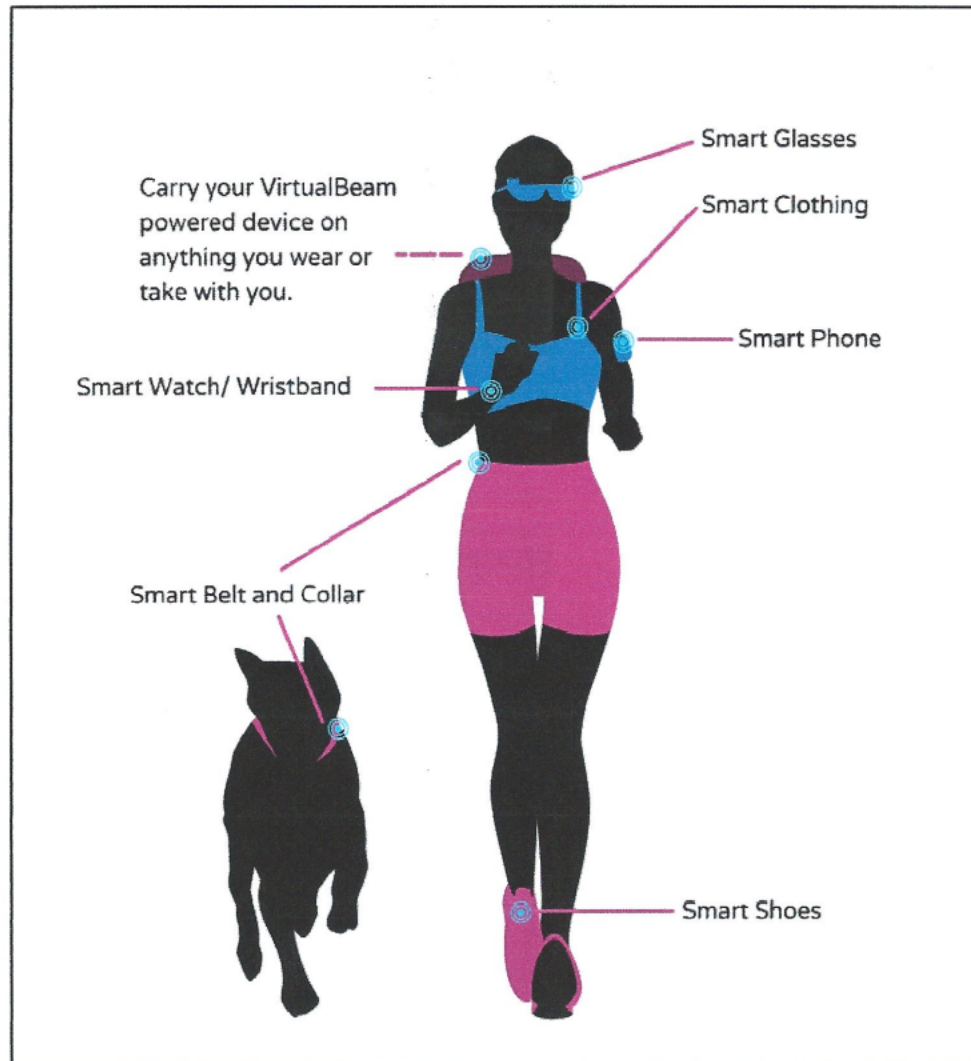
At VirtualBeam we have developed a scalable, "featherweight" HAR software platform that can serve multiple wellness, health, medical and fitness markets including the sleep monitoring and diagnostics for the health sector, and various other industries such as public safety, emergency services, industrial safety monitoring and opportunities for the military.

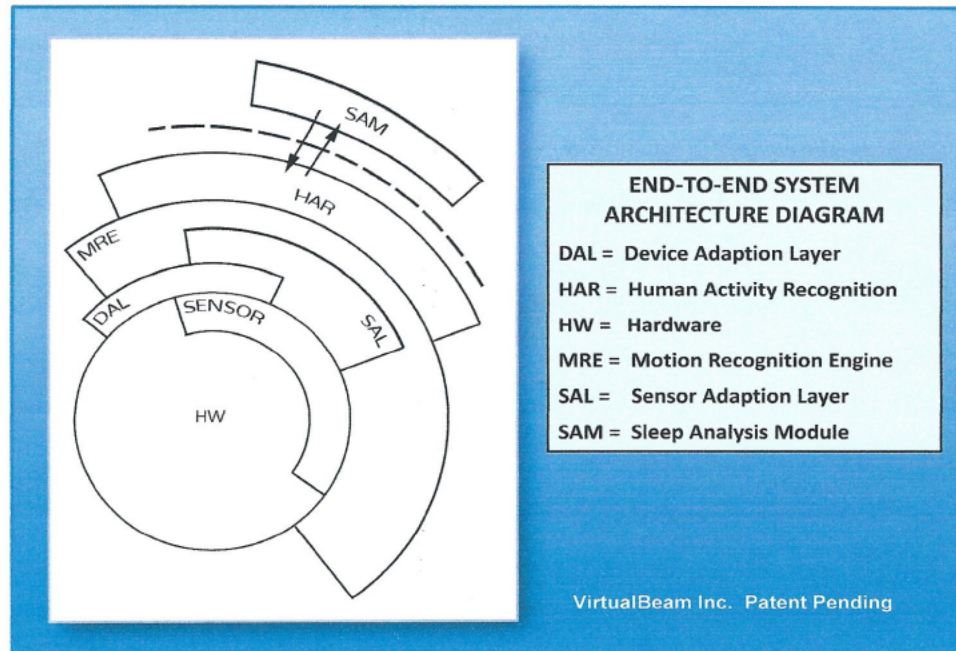## VirtualBeam Inc. Product Video and Brochure on Website:

http://www.virtualbeam█████

and on YouTube:

https://www.youtube.com/watch?v=pRkjo4yxofU

Carry your VirtualBeam powered device on anything you wear or take with you.

Smart Glasses

Smart Clothing

Smart Phone

Smart Watch/ Wristband

Smart Belt and Collar

Smart Shoes

Software for the Internet of Smart Things

VirtualBeam, has developed a software framework for the Internet of [Smart]Things to support the operations of two unique engines, ("motion" and "emotion") which give a device a semi-human-like sense! The engines run on mobile and wearable devices to enable delivery of new use cases, mobile services and applications or enhance existing ones. The "human activity recognition engine" or HAR engine, is software developed by VirtualBeam which gives a mobile / smart wearable device, such as a smart phone, smart watch, smart ring or smart pair of glasses a fine sense of movement and motion as the user moves within space. Using this sense, a device can recognize natural body movements in real time and inform / provide data to other applications or services. One distinctive property of the software engine is that it can fit entirely on the device. The engine reads raw data from hardware and converts it into meaningful messages applying complex and newly developed algorithms.

END-TO-END SYSTEM ARCHITECTURE DIAGRAM

DAL = Device Adaption Layer
HAR = Human Activity Recognition
HW = Hardware
MRE = Motion Recognition Engine
SAL = Sensor Adaption Layer
SAM = Sleep Analysis Module

VirtualBeam Inc. Patent Pending

The motion engine is designed to monitor a range of human natural movements for routine fitness and health purposes. But it provides much more information such as how you sleep, monitors detailed sleep patterns, and can produce digitized granular semi-medical-grade Actigraphs with valuable data that is readily available to the end users or can be shared with health providers or other for further data analytics. All fitness or health tracker application and mobile devices (e.g. products by FitBit, Apple, Google, Samsung, Jawbone, Garmin or other) would benefit by running the motion engine because it delivers a digitized sub-second granular map of human activity. In terms of activity tracker, the motion engine delivers far beyond just a mere Pedometer, or "number of steps." Among other capabilities, the engine detects the finest motion during sleep, and can recognize non-natural body movements including falls. The engine can be utilized in many new applications and across different sectors; routine exercises, public safety operations such as police work, and military exercises, to name a few.

The motion engine delivers, in a predictive and deterministic fashion as its main function, messages that indicate natural body movements such as running, walking, turning, sitting, rolling, rising, falling and others. It also generates semi-medical grade reports and analysis of inactive time periods such as sleeping and resting patterns.

The emotion engine intelligently learns the users' habits and connects users to people or objects of interest. Licensed separately, the emotion engine can collaborate with the motion engine to map human movement in relation to the surrounding environment. This enables a savvier modeling of human activities by building associations with surrounding people or objects of interest.

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The motion engine has a very small footprint (15K to 115K for the complete instruction set and data, including the runtime environment) through innovations in smart algorithms that require minimal memory space. The entire software engine can easily fit on many devices, such as a smart-band or -watches, etc. The engine meets requirements for extremely low system memory and provides extremely fast response time in sub-seconds. The core of the code base is written in C which is binary compatible across different platforms reducing the cost involved in the rewriting or porting software.

Wellness and Activity Sharing

With options to recognize and share human activity (such as walking, running, sitting, etc.), an autonomous self-aware device can take sleep and activity management to new heights. VB HAR on-device service is accurate and fast with real-time recording and playback of an individual's natural body movements even during inactive periods. The service allows real-time monitoring of children and the elderly. Subscribers will be able to share information on the activities and use their own or third party messaging services. The information can be shared by using a network provided either through the VirtualBeam IoT platform or other messaging platform. All the platform needs is a connection to the Internet. It piggybacks on messaging services integrating with the users email services, tweets, telegram, and more. Users can easily share their activity of interest, with other trusted people or parties as a result. Available for licensing, this platform offers private and secure sharing of information.

Detailed Actigraphs

Running the motion recognition engine, our Wellness and Sleep Monitoring platform offers cost effective solution to low-cost at-home or in-clinic sleep diagnostics through use of our technology that outperforms existing professional sleep monitoring devices.

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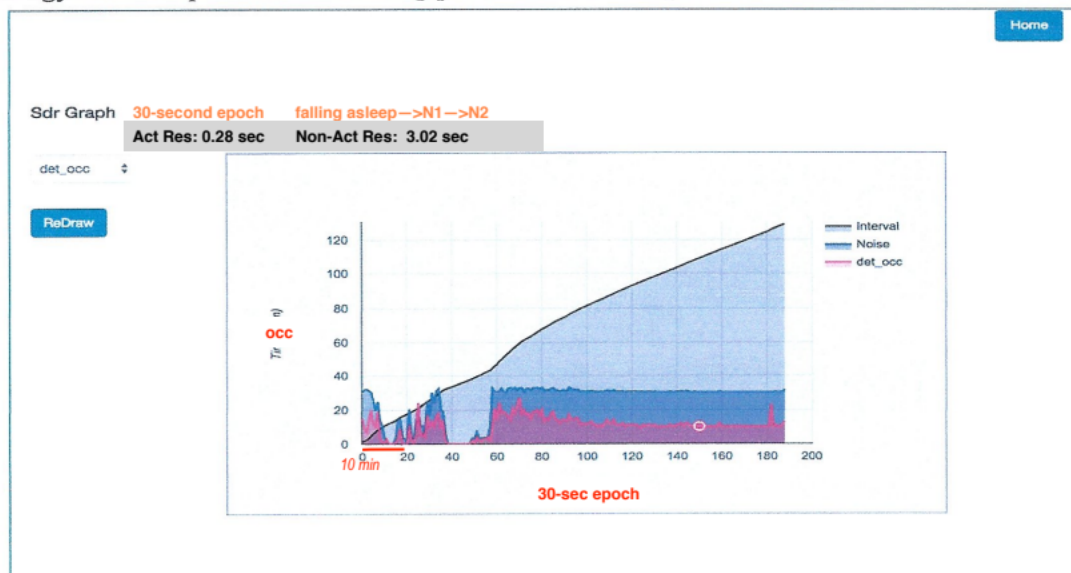
Having run VBHAR with Sleep Analytics library on-device on hundreds of smart-watches and -bands, we have been able to create digitized Actigraphs superior in quality and accuracy to those produced by the most advanced medical-grade systems. The engines generate data sets that feed infographs. Results are discrete graphs that a physician or sleep expert can digest in a few minutes, in contrast to noisy [accelerometer amplitude] graphs that are available to physicians today. VirtualBeam digitized Actigraphs allow the frame by frame mapping and analysis of User sleeping patterns. The platform allows users to self-monitor active, rest and sleep patterns and opt to share the information with health providers.

The VBHAR Service Platform offers standardized data feeds to Cloud for physicians and other health providers, at much lower costs than in-clinic or at-home sleep and health clinics. The platform can also be used by clinics to monitor patients in real-time at lower cost compared to the existing systems in use today. This allows insurance companies to pre-approve a less costly alternative to costly in-lab tests. It also allows insurance companies to focus on pre-certifying home sleep monitoring, reimbursement of insurance claims for home sleep testing, and specifying which devices may be used. With the obvious shift from in-lab sleep centers due to high costs to the much larger pool of primary care physicians who wish to monitor obstructive sleep apnea in patients first-hand, this platform can quickly replace or enhance the devices used by in-lab sleep centers and give health providers and physicians the choice of working directly with the patient to self-monitor sleep apnea or perhaps other problems during sleep.

Due to its superior software technology, the VirtualBeam product can generate detailed messages or signals of activity such as "falling asleep", "asleep beacon", "waking up", "awake status", "hyper-active patterns", and more autonomously. This is based on our proprietary analytical models and algorithms, allowing coverage of even inactive times such as "sleep or rest periods".

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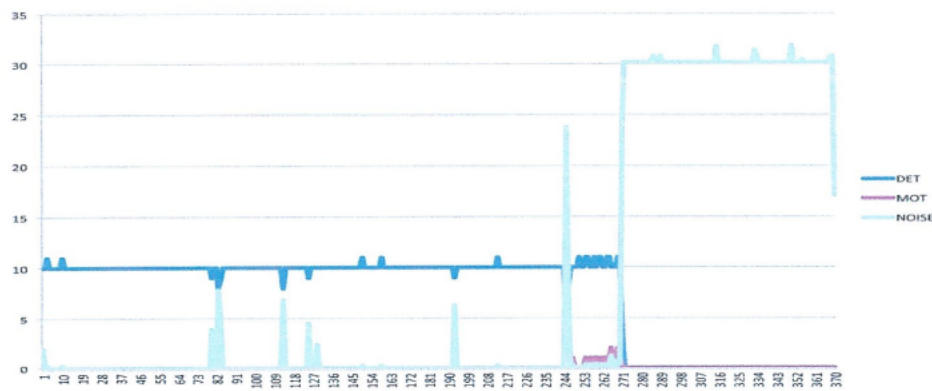
VirtualBeam software can therefore generate discrete digitized and "accurate" Actigraphs on-device, compared to analog, noisy, and inaccurate graphs generated by much more expensive devices and support systems currently available in the markets.
The software is capable of using inexpensive combinations of accelerometer /gyroscope/and other sensors (navigation, audio, light, temperature, and pressure sensors, EKG and EEG input, I/F to devices , Body Area Networks to obtain body vital signs, etc.) to increase for example the quality of sleep monitoring through consumer electronics devices with higher capabilities such as smart-watches or smart-bands.

Pilot Projects - Trials and Demonstration Kits

VirtualBeam offers product demonstration kits to potential clients. These include a mobile application software development kit or SDK, and devices with complete test-bed to experiment on: The software engines are portable and have been tested on more than hundred different models[1] of smart-bands, -watches, -phones and other devices, both in our lab and at third party test laboratories for independent benchmarking.

Demo applications are also available for Android and iOS devices with the C part running in Java and/or Objective C environment.

With the SDK, the application designer can experiment with the engines and the platform. The designer can replace a simpler engine with our engine, or complement a step counter with our engines to obtain a richer and more accurate reading . The SDK, with professional services by the VirtualBeam team, can be used to test the services platform end to end and build applications that need Cloud support.

Software Licensing and Subscription

The VirtualBeam software products are offered through licensing of our e | motion™ product line, The "wearable software" platform for example, can be offered to conquer electronics market under a revenue sharing model or subscription-based service model. Our main products for licensing are the motion engine and the emotion engine. The motion engine was discussed earlier in this document. It has a small footprint and is significantly more accurate and order of magnitude faster than the tiny pedometer software now norm on almost all devices. The competition may claim they have the features, but records show that their activity-tracker products are simply "step counters."

In addition to continually improving the engines, we are working on an IOT software platform which can deliver some intuitive subscription-based services.

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[1] list of brands include: Apple, Huawei, Xiaomi, SONY, SAMSUNG, Google, LG, HTC, Motorola

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Partnering with VirtualBeam

VirtualBeam has established agent/principal and business partnerships with high technology companies in Asia and in Europe. We expect the number of agents and customers to grow over the next 12 months including North America. Contact us for more information.

Contact Information

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