Creating the Future of Brain-tech with Brain wave AI Platform

Hideki Matsubara
CEO, PGV Inc.

1. Founding of PGV

PGV is a startup enterprise from Osaka University, established in September, 2016 to create a practical implementation of results from the research of Professor T. Sekitani, of the Institute of Scientific and Industrial Research (ISIR, or SANKEN) at Osaka University. Professor Sekitani conducts research on flexible electronics technologies, and he has attracted attention from around the world in this field. He has achieved excellent research results with technology using highly elastic electrodes to accurately capture brain wave data, which is particularly difficult to measure, even compared to other biological data. PGV was established to implement a patch-type electro-encephalograph (EEG) device based on these results. With this patch-type encephalograph device, PGV aims to become the technology leader in the brain-tech market.

2. Characteristics of brain wave data

With brain activity, tiny electrical currents flow in the brain. Electroencephalograms (EEG) are a record of electrical activity produced by nerve cells in the brain of a person or animal, taken using electrodes placed on the scalp or other locations. They have two characteristics that differentiate them from other biological signals such as pulse, heart-rate or myoelectric (muscle) signals.

The first is that brain wave response is extremely fast. During human activity, the brain must process and send instructions to each part of the body before that activity. For example, when one is nervous, the pulse and heart rate increase, but the brain feels the nervousness first, and then sends instructions to the heart. Thus, its response is faster than pulse, heart rate or myoelectric signals.

The second characteristic of brain waves is that they carry more information. Brain waves are signals that change with a modulation width of roughly 0 to 50 Hz. They also change without regulation or pattern. For example, when you are reading a book, watching a movie, or listening to music, the waveforms of brain waves are different in each case. In contrast, pulse and heart rate have a set pattern; a fixed waveform centered around 60 to 70 Hz, getting faster or slower according to level of stress (autonomic nerve action). Differences in the book, movie and music experiences can be distinguished from brain waves, but such differences cannot be classified easily from pulse or heart rate.

Brain waves have these characteristics, but they are difficult to handle because they are extremely small signals and have complex waveforms. Pulse and heart rate signal strength is in the range from 1 to 10 mV, but brain wave signals are only 1 to 50 μV, and unlike pulse and heart rate, brain waves also occur with an unlimited number of waveform patterns. They are also measured together with myoelectric signals due to the movement of eyelids and eyeballs, and this adds to the complexity of the waveforms. As a result waveforms can be different, even for the same activity or state, making analysis to select the common components very difficult.

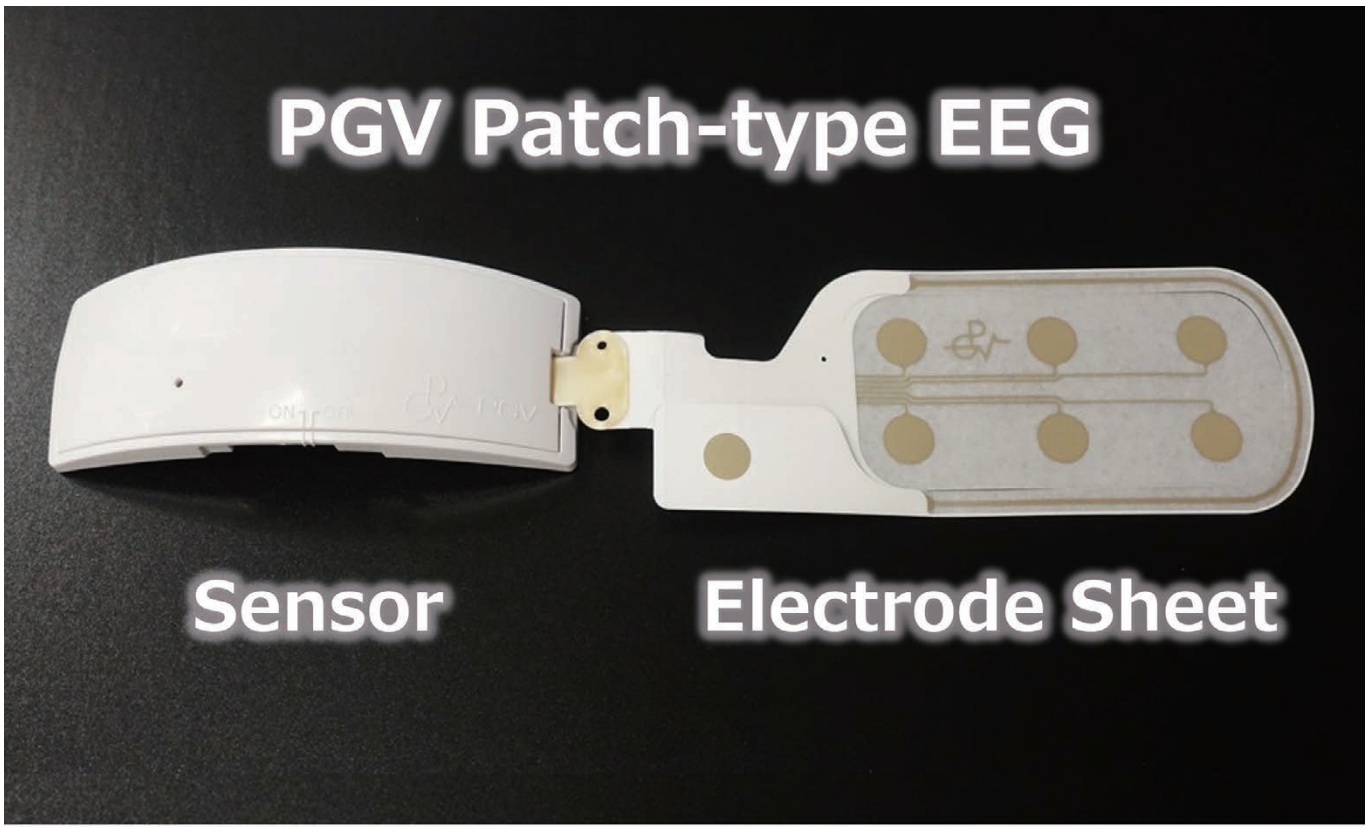
3. PGV Strengths

As can be seen from the above characteristics, useful and effective utilization of brain waves requires 1) the ability to accurately and easily measure brain waves, which are very weak biological data, and 2) to overcome the difficulty of analyzing these measurements.

For the first point, we have implemented a patch-type EEG (Figure 1) product using flexible electrode sheet material by combining Prof. Sekitani's research results with expertise from Nippon Mektron Ltd., a world leader in the field of flexible printed circuits (and a member of the NOK group, which is a PGV shareholder). In the past, brain waves were measured using large, medical EEGs, but their range of use was limited because they required up to 30 minutes to set up, they placed a heavy burden on the subject, and they were very expensive systems. PGV's patch-type encephalograph is extremely easy to use compared to conventional large EEGs, and is able to obtain brain wave data without compromising accuracy. The electrode sheets used to measure brain waves are a patented technology that is an extremely thin 50 μm, has excellent elasticity, clings tightly to the forehead, and fluctuates very little in resistance, so the subject's minute brain wave signals can be captured. The device also uses excellent noise processing technology to achieve stable EEG readings.

For the second point, we have incorporated AI in analysis of brain waves and are accumulating know-

Figure 1: PGV's patch-type EEG



how in efficient analysis of brain wave data. Brain wave fluctuations do not show patterns and appear to be irregular. As such, even when performing a frequency analysis, there are many dimensions that are beyond the scope that a person can understand. It is extremely difficult to derive patterns linking brain wave changes with changes in the body or mind. This has lead to use of AI analysis. In AI analysis of brain waves, large amounts of brain wave data labeled with the person's activity or state are collected and they can be analyzed to make associations between the person's activity or state of mind and body and the brain waves. By developing many brain wave AIs in this way, it may also become possible to understand various states of a person's mind and body objectively, by measuring their brain waves.

4. PGV's business—Now and in the future

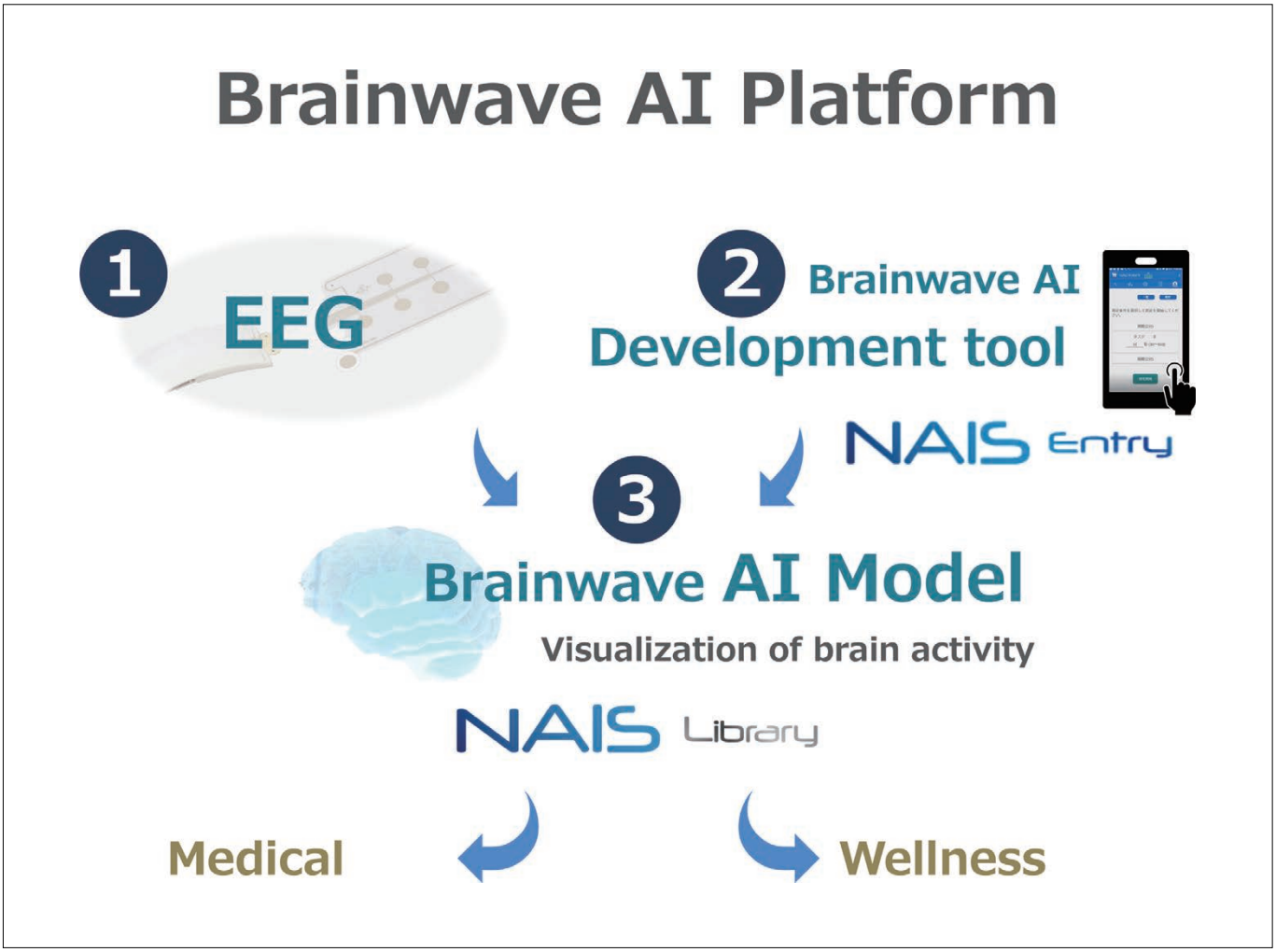
So far, most of PGV's work has been in developing, manufacturing and selling the patch-type EEG, and contracting services related to brain wave analysis.

PVG's patch-type EEG sensor is small and light-weight (27 g), is hardly noticeable when worn and is controlled wirelessly, making it very easy to measure brain waves. As of August, 2020, it has also received medical device certification (Class II, 302AFBZX00079000) as a telemetry EEG. It is helping to make clinical research using brain waves at universities and research facilities less expensive and more effective.

Our contract services in brain wave analysis involve medical research and also a range of research involving the five senses and other bodily states (fatigue, concentration, etc.). Our customers include university and other research facilities as well as enterprise R&D departments and new-business development departments. We have been performing frequency analysis of brain waves, but as mentioned above, since FY2020, we have been using AI based on the characteristics of brain waves.

To raise our competitiveness in the brain-tech market, we are promoting a brain wave AI platform concept. The platform is composed of three elements: (1) an EEG, (2) a brain wave AI development tool, and (3) brain wave AI models (Figure 2).

Figure 2: Three elements of the brain wave AI platform



Regarding the first element, we have begun developing a next-generation EEG. We are pursuing a more compact and user-friendly EEG while maintaining high accuracy, to further advance the current EEG. In the future, we plan to develop an AI chip, and automate brain wave pre-processing (data cleansing) and other tasks that require a large amount of effort to be invested.

For the second element, the brain wave AI development tool, we formally released the NAIS Entry brain wave AI analysis service in May 2021. Although the EEG is easy to use, the brain wave data is difficult to handle, so this service provides AI analysis of measurements that our customers have taken themselves, in an SaaS format. We implement brain wave analysis that is easier and costs less. Users first use a PGV device to measure brain waves, which they then upload to PGV servers using an application on a tablet. The results of AI analysis of the user's brain wave data are then sent back to the user. We plan to continue improving NAIS Entry functionality, to more precisely meet the needs of various types of customers.

For the third element, the brain wave AI model, we have consolidated various algorithms from both medical and non-medical fields in to our NAIS Library, and are working on visualizations of brain activity as a measure (an objective index) of brain waves. At PGV, we have already completed development of a brain wave AI model for sleep analysis (automatically determining stages of sleep and generating sleep indices). In the future, beyond development within PGV, we will strengthen our support

for external AI model development, providing our patch-type EEG and NAIS Entry service to other enterprises and research facilities. Our brain wave AI platform is positioned as a service platform promoting Open Innovation in the brain-tech field.

In medical fields, we hope to use brain waves as a biomarker for mental and nervous-system disorders. For example, brain waves could be used to diagnose dementia. We have already prototyped a program to diagnose dementia, but we are still collaborating with the Faculty of Medicine at Osaka University to improve its reliability. In the future, we will conduct clinical trials to verify the technology and hope to commercialize a brain wave AI program for diagnosing dementia (obtaining certification or approval as a Software as a Medical Device). We plan to implement a system that can be used for a preliminary diagnosis of dementia using brain waves, which can be done by a primary-care physician, even if they are not a specialist in dementia. This will contribute to the treatment of dementia as is needed in our hyper-aging society.

As of FY2021, we have also begun developing a NAIS Library for a non-medical field, visualizing people's state of fatigue and mindfulness, and using brain waves as an objective index of fatigue.

Finally, I would like to introduce PGV's long-term vision of "Brain health management with an EEG in every household." We hope in the future, to implement an EEG and brain-health management program for home use, by further improving our EEG so that it can be used easily by the general public, and by using evidence and brain wave AI models obtained through initiatives in the medical and health-care fields. We have about 15 technical employees (data scientists, software and hardware engineers) who are focused on implementing this long-term vision and working daily to improve performance in the brain-tech industry.

Figure 3: NAIS Entry service flow