HEALTHCUBE PLATFORM

Blockchain-Based Healthcare Platform Service Employing Artificial Intelligence Technology on Big Data of Signals from Human Body Measured by Smart Devices
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### Summary

**What is the “Quartet of Death?”** It refers to hypertension, hyperlipidemia, central obesity, and impaired glucose tolerance which is a probable precursor of diabetes. This is called metabolic syndrome in medical terms. When the four parties start playing, your blood vessels begin to be clogged slowly, and the blood vessels of your heart and brain are no exception. Unfortunately, there is no nerve in your heart and blood vessels, so you have no symptom even if they are 80% clogged, and you lead your daily life unscathed until you suddenly collapse that you have to be carried into an ambulance. This is why some call myocardial infarction "a silent assassin."

It is a global phenomenon, with the number of patients with stroke or heart disease exploding due to such cause. According to the World Health Organization (WHO), heart disease is the unrivaled number one cause of death. Of all the deaths across the world, 17.7 million people -- accounting for over 31% of the total number of deaths -- lose their lives to cardiovascular diseases every year. The same goes for the Republic of Korea, so the country as of 2016 has around 625,000 patients with angina -- or having narrowed heart arteries -- and around 35,000 patients with acute myocardial infarction. The country has even more patients with arrhythmia, or having irregular heartbeats, which numbers almost one million according to a society.

Other developing countries are also seeing an increase in chronic lifestyle diseases such as hypertension, diabetes, and hyperlipidemia. The problem is that the increase in patients with such diseases does not stop. This is because the patients are “mass-produced” by western eating habits involving high-calorie, high-fat foods, lack of exercise, smoking, stress, fine dust, etc. combined. Especially, you need to pay attention to Asia with regard to the increase in cardiovascular diseases. Scholars compare Asia -- which is enjoying material affluence thanks to economic development within a short period -- to “the powder keg of cardiovascular diseases,” noting that the exploding number of Asian patients with such diseases reminds one of a war. For instance, China as of 2017 has around 36 million patients with cardiovascular diseases.

Listing such cases is a daily thing, which is neither special nor new. You get myocardial infarction without warning like this. Thus, paradoxically, patients with myocardial infarction may somewhat envy cancer patients who are terminally ill but can at least prepare for their death. In modern times, which boast of cutting-edge medicine, it is truly unfortunate to live not even knowing that there is risk of cardiovascular diseases inside your body. Just like Mr. A, who takes his backpack to go to a mountain excitedly while his own life is in danger, we are living with no foresight.

**Smart Stethoscope for Households**

But what if you have a measuring unit for simply checking your heart's condition? If you can check the condition of your heartbeat as well as for any sign of problem before going to a mountain or while climbing the mountain, you can prevent such an unfortunate event. Those belonging to a heart-related high-risk group such as smokers, those experiencing a lot of stress in their jobs, and obese people
with lack of exercise can enjoy the usefulness of the measuring unit, which enables them to check their heart's condition frequently. Those with family history of heart disease would have greater need for such device.

Patients with diabetes take care of their health by measuring their blood sugar levels every day, making efforts to lower the levels by changing their meals and exercising more if the levels are high. In addition, an electronic blood pressure monitor and an electronic thermometer have become a useful necessity for healthcare at all households since they notify a dangerous level. Note, however, that there had never been any device in the whole world for checking the health condition of your heart, which is directly connected to your life, at home -- that is, until the release of the smart stethoscope "Skeeper." Those healthcare devices for the home such as the Skeeper, which helps you check your heart's condition not only in daily life but also before and after exercise, whether you are stressed or not, and when you are in a special situation requiring taking care of your heart, are newly released, being of great help to modern people in taking care of their health.

**Hear and See Your Heart Sound**

Why is it important to hear your heart sound? Your heart pumps 24 hours a day to send blood with much oxygen from your lungs to all cells in your body. Here, if your heart is healthy, it makes a normal heart sound. If it has a problem in your cardiovascular system, it makes a cardiac murmur. A stethoscope is a diagnosis tool that allows your doctor to hear the sound that your heart makes and to find out if your heart has a disease or not. To make an accurate diagnosis, your doctor needs to have experiences and skills.

Meanwhile, easier and more accurate diagnosis equipment for doctors have been developed, which include echocardiograph and angiography equipment. Note, however, that such equipment cannot be used at home because of their price, scale, and expertise requirements, so the Skeeper was developed to make taking care of your heart easy in everyday life by hearing and visualizing your heart sound considering such usability at home. A traditional way of auscultation has the following merits: it does not make the user uncomfortable; it is cheaper; it is convenient since it does not use contrast medium or radiation; and it is not harmful to the human body. The Skeeper's technology lies in the acquisition of your heart sound by a high-performance acoustic system and visualization of the sound via an SW algorithm developed by the manufacturer of the Skeeper and realization of such results in various types in a mobile application linked to the device. It is able to accumulate objective, detailed analyses, records, and data, which could hardly be provided by the existing stethoscopes.

Thus, you can now take care of your heart and that of your family in your daily life by measuring your heart sound and that of your family at home. The Skeeper is available as a primary screening device at home. Especially, the Skeeper can help build infrastructure such as telemedicine even in an environment with insufficient specialists and special medical institutions such as third world and developing nations to provide medical service for a broader region; thus contributing to easing the inequality in health across the globe.
Healthcare System Evolving with Emphasis on Prevention and Households

IoT (Internet of Things) refers to the technology for attaching a sensor to things and exchanging information acquired in real time. Its key technologies are Bluetooth, near field communication (NFC), sensors for acquiring data, and network for transmitting data. As a new concept of IoT healthcare device, the Skeeper is able to measure bio-signals such as heart sound and lung sound and to transmit such information to your smartphone via Bluetooth, thereby sharing the accumulated health information with a doctor for taking care of your health. HealthCUBE aims to use such IoT healthcare devices and to develop a healthcare platform that provides various healthcare solutions and services. In other words, we can make a new healthcare ecosystem that has not existed until now by making big data from numerous pieces of biometrics obtained from users of IoT healthcare devices such as the Skeeper and using artificial intelligence (AI), and we aim to achieve the following performances:

First, analyze the enormous biometric data collected and find out patterns of diseases, thereby enabling the estimation of a disease before patients even visit a hospital and recognition of the necessity to visit a hospital. In case of the heart, if you can analyze the information acquired via the Skeeper and learn whether an emergency such as myocardial infarction will occur or not, you will be able to save a number of lives. Through these processes, you can help realizing customized precision diagnosis and predictive medicine.

Second, the prior diagnosis function of artificial intelligence through big data analysis is able to minimize subjective deviations among doctors due to individual experiences. Though a mistake in diagnosis may occur in accordance with the fatigue level of doctors during diagnosis or in various circumstances, an analysis by artificial intelligence based on big data is expected to be able to minimize such mistake, increase the accuracy of diagnosis, and supplement the diagnostic capabilities of individual doctors.

Third, the connection between homes and hospitals will be strengthened. Currently, you have to visit a hospital to be diagnosed; if you use the HealthCUBE platform, however, you can get a diagnosis in advance at home and receive telemedicine by sending the results to a doctor. While the Republic of Korea still has regulations on telemedicine, countries that realize advanced medicine such as, the US and Japan are reinforcing telemedicine.

Currently, medical systems focusing on hospitals worldwide, especially in advanced nations, have a high-cost, low-efficiency structure. Governments of many countries also recognize that it is hard to pay the huge medical bills incurred because of the aging population given the current medical systems. This is why healthcare puts special emphasis on prevention, healthcare in ordinary times, and households from here on.
## Birth of the HealthCUBE Platform

In this global medical environment, you can use IoT healthcare devices to check your family’s health condition and receive health analysis service via a healthcare platform based on artificial intelligence. If you want more professional checkup and prescription, you can receive telemedicine service from a healthcare professional for an area via an online channel or visit a medical institution and get treatment. We named our healthcare platform based on artificial intelligence for realizing such new medical ecosystem "HealthCUBE," and we aim to embody it as a customized healthcare platform service that provides the services needed for individuals' healthcare ranging from health checkup at home to health analysis using artificial intelligence to telemedicine by healthcare professionals and to treatment at hospitals.

In the US, as of 2010, those who used the personal health record (PHR) accounted for 7% of the total population; this means that the PHR was used very actively. Even global enterprises such as, Microsoft and Apple are releasing PHR services. HealthCUBE is an individual personal health record platform. Note, however, that it is a service platform using health data that does not remain as an existing personal health service recorded by individuals and used only by individuals but collects, stores, and analyzes the data of measurement by individuals to verify the effectiveness of the data and to assign value; thus increasing the added value of the data.
HealthCUBE Platform Service Models

Demander-centered customized medical service
- All family members’ health is managed using smart devices and HealthCUBE at home at usual times and rewards are made by token.
- When there are abnormal symptoms, examination and medical treatment are received through hospital visits or telemedicine services and rewards are made by tokens.

Health-related Customized Products
- Rewards are made by tokens in return for the sale of one’s health & medical treatment data, watching advertisements, clinical trial & experience group participation, and etc.
- Tokens are paid when insurance products, healthcare devices, health foods, and etc. are purchased on the e-market.

Donation and Pro Bono Activities
- Donations are constructed through the activities of all participators in the ecosystem and use details are transparently disclosed to all at ordinary times.
- HealthCUBE supervises all donations and pro bono activities by establishing the charitable foundation (H-CUBE Aid Center).

This project aims at not only taking care of individuals’ health via HealthCUBE but also enabling the development of new medicine and insurance products, performing marketing, planning various health products, and providing guidance for the health policies of the governments. HealthCUBE will divide the global market into seven areas to prepare a foothold for contributing to the development of the healthcare industry in each country based on strategies that meet the demands of each area.
To sum up, if the HealthCUBE platform begins to work, self-healthcare will spread with focus on homes, and accessibility to medical service will improve in general. Accordingly, it is expected to narrow the gap in the treatment level between medical professionals, to help relieve the inequality in medical service between regions, and to contribute to the improvement of medical services for the health of mankind.

Strategic Alliance between HealthCUBE and Smartsound

Skeeper, the Smart Stethoscope for home use, is a smart healthcare device based on IoT that is developed, manufactured and sold by Smartsound. It is commercialized as the world’s first in 2017, and is being used by three mobile applications pairing through BLE.

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<th>Skeeper Mama (For pregnant woman &amp; fetus)</th>
<th>Skeeper Baby (For Infant)</th>
<th>Skeeper Heart (For Adult)</th>
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<tr>
<td><strong>Skepper mama.</strong></td>
<td><strong>Skepper baby.</strong></td>
<td><strong>Skepper heart.</strong></td>
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Smartsound was founded in November 2011 with a vision to become the world’s leading provider of smart healthcare solutions for households by developing smart home healthcare solutions based on sound processing technology. After many years of research and development, Smartsound commercialized Skeeper successfully and has been actively developing its business in domestic and foreign markets. Smartsound has won numerous awards for its excellence in product recognition, and became the first Korean company to win the IoT Trailblazer Award at IoT Asia 2018, held in Singapore in March 2018. In May 2019, It won the d&i Award for the IoT division at COMPUTEX in Taiwan.

HealthCUBE develops and operates ‘HealthCUBE Platform’, a personalized healthcare platform based on smart devices and solutions, through the exclusive strategic alliance with Smartsound, which has excellent competence and provides various forms of solutions and services in global markets including Korea. Providing
services that lead to 'Device → Solution → Platform' In the Value Chain, Smartsound is responsible for the development and supply of devices and solutions. HealthCUBE establishes a permanent strategic cooperation structure for comprehensive platform development / operation. By commercializing the HealthCUBE platform service, HealthCUBE will establish a leading position in the global market.

**Blockchains in the "HealthCUBE Platform"**

The personal health record (PHR) that HealthCUBE aims to deal with is not medical record in the early stage but personal health record based on heart sound data to be expanded into record on lung sound and other bio-signals. The PHR must be managed by individuals in terms of its features; for the PHR with individuals as subject, the following elements of blockchains must be applied:

- **01** Reliability and integrity of data
- **02** Security and transparency of data
- **03** Reasonable costs for data management
- **04** Proper compensation to individuals providing the data for use.

Therefore, if the PHR is built in a cloud using blockchains, such will pave the way for broadly using medical information while keeping the current medical systems. Such medical information system will not only have a positive impact on the entire medical circles but will also help provide proper medical service to patients.
02 Personal Health Record and Blockchain Technology

2.1 Personal Health Record (PHR)

Each time an individual receives treatment, a great deal of data related to the treatment are generated in the hospital, and the individual’s own devices also create additional health-related data.

The personal health record (PHR) is one way of receiving treatment and healthcare from healthcare professionals based on past treatment data of hospitals and health-related data directly entered by the user or collected from information devices under various circumstances in daily life. The PHR is a newly emerging area in the healthcare industry.

On the other hand, the electronic medical record (EMR) can be said to be a health-related electronic record that is created, collected, managed, and controlled by healthcare professionals and medical teams permitted within a single medical institution.

The management of the PHR is a concept that allows individuals to check such health-related electronic record and to share and control the record. The PHR includes not only those data provided by medical institutions but also those data entered in person by individuals (data automatically created by devices or data entered by individuals), so both medical institutions and individuals are the subject of data production.

Since individuals assume all responsibilities with regard to data distribution, if only the issue of security is settled, we can be free from legal issues caused by data distribution. If the PHR selects a negative regulation on data distribution, and there are more and more items that are not permitted, however, such will hinder the active use of the PHR service in society.

The PHR consists of the following: individual PHR; PHR connected to EMR; and mutually connected PHR. The individual PHR contains only the data entered by individuals, so it totally depends on the records by the patients, which hardly contain professional medical knowledge. Since it does not depend on medical institutions, however, it is easy to realize and is free from legal issues. Accordingly, it is a method that can be first realized in the areas of big data analysis and distribution.

In the US, its use is very active such that the population using the PHR has already reached 7% in 2010. The Blue Button, which is provided by the Department of Veterans Affairs in the US, can be called a PHR connected to EMR to allow the reading and downloading of individuals’ treatment record via the Internet. As a personal health record service led by enterprises, Microsoft Health Bot enables individuals to manage comprehensively and in person the treatment record, vital signs, etc. via data connection with participating hospitals. Apple is working on a project to make the iPhone the hub for personal health record.

In the Republic of Korea, there is My Health Bank of the National Health Insurance Service as a personal health record service. Users can read via this service contents such as treatment, administration, medical checkup, and insurance premium and can personally enter the information that they want to manage on their own such as height, weight, and blood pressure. Since this service provides information based on the claim data of the National Health Insurance Service and has no connection to medical institutions, however, it provides only a low-level personal health record.

The PHR service connected to the EMR provides healthcare, administration management, treatment service function, health information, etc. to patients who have received treatment in an individual manner from a hospital as a unit of medical institution, and you can make a reservation for treatment or medical checkup, etc. Nonetheless, this service fails to provide medical information integrated with that of various medical institutions since it is limited to some specific hospitals.
In conclusion, to activate the personal health record, we ultimately need to introduce actively a link system to provide a personal health record service standardized at individual hospitals. To ordinary people, however, professional medical knowledge provided by the electronic medical record is just like some secret code. Many parts of such knowledge are in English, and professional medical terminology is used; thus, even if they read their own health record, they cannot grasp the meaning.

To make this service accepted by society, we need to form an ecosystem for personal health record, and a stepwise evolution process is required for a service model that provides actual benefits to patients as the ultimate beneficiaries of such service.

In addition, as the concept of personal health record is emphasized, the recognition with regard to the subject of medical data is changing from the medical institutions to individuals. This means that individuals' participation will become very important in various activities conducted in the healthcare ecosystem.

### 2.2 Personal Health Record on Blockchains

On the Internet, a huge volume of personal information is being exposed and distributed, but the medical records of hospitals are difficult to distribute because of their closed environment. If the production of medical information and personal medical information becomes generalized, however, it will not be difficult to find such information online. Medical information has a high risk of leak just like personal information. Still, the areas of medical information that individuals can produce are limited and shallow, so the current legal regulations focus on institutions that deal with medical information. As the possibility of individuals producing their own medical information or personal health record increases, however, the laws will be reorganized, and proper systems will be prepared as well.

The part of "Personal Health Record" that HealthCUBE wants to deal with is not medical record but personal health record based on heart sound data in the early stage and expansion of such as records based on smart devices, including records on lung sound and other vital signs. Therefore, in the early stage, the focus will be on such part to target all processes and systems; as the usability of devices increases and the analyses of health record are conducted more and more precisely, however, the possibility of medical institutions becoming connected to each other and exchanging data with related industries will rise. Accordingly, when we handle blockchains (we will proceed with actual realization by step, but we aim to handle even the slightly distant future for those matters that should be considered), we cannot but think about this part, too.

In this connection, the parts to consider are as follows:

For the ultimate personal health record service, which connects the treatment data contained in the electronic medical record scattered in accordance with individuals' visits to hospitals, the claim data managed by medicine-related public agencies, and the health-related data collected and managed by individuals, strict security for personal medical information -- which is the most sensitive part among personal information -- and stability with no forgery or falsification must be guaranteed. Unless this issue is settled, you will inevitably remain at the level of limited, individual personal health record service. We believe, however, that this issue can be settled by blockchains.

The personal health record (PHR) must be managed by individuals in terms of its features. This means that individuals must manage and take responsibility for the data provided by medical institutions and public agencies as the existing subject of managing such data. For the PHR with individuals as subject, the following elements of blockchains must be applied:
First, the reliability and integrity of data.

When individuals become the subject of managing medical data, the medical data can be forged or falsified by the individuals. This fact is a problem for the final users of the data distribution. In other words, rubbish data make rubbish results.

Second, the security and transparency of data.

If individuals become the subject of distribution of medical data, vulnerable medical information of individuals might be exposed because of careless management. In addition, as medical data are distributed, such medical information might be used randomly by a third party without the consent or knowledge of the data's owner. Therefore, it must be possible for individuals to monitor sufficiently where, how, and for what purpose their own data are used.

Third, the costs for data management.

If an individual bears all costs for security, storage, transmission, and management of all of his or her data related to health and medicine, only an extremely small portion of the entire population will manage their own personal health record. Then, there must be a method of reasonably bearing the cost.

Fourth, if an individual provides his or her data, proper compensation must be given to him or her regarding the use of data.

This point may be related to data distribution. So far, freely using the medical data of medical institutions has been allowed if only the regulations of the National Bioethics Committee are observed and there is no special reason otherwise. Considering the fact that the subject of the data is individuals as well as the issue of activation, however, there must be some compensation for the individuals for their provision of their own data.

Currently, the medical paradigm is shifting from the concept of treatment to that of management. What is important in management is to record not only the existing information on diseases and treatment process but also the daily, periodic information of health condition.

The focus is shifting from an environment where medical information is recorded and stored in an EMR system to a system where the EMR information and personal health information of individuals at home are integrated and stored as PHR.

Such type of PHR makes it very easy to identify the health condition of patients, so it is appropriate for providing medical services to patients. Note, however, that the current EMR systems are made in different types depending on the medical institutions, and it is hard for the medical information to be integrated into the PHR.

The cloud is an environment that facilitates the building and processing of an integrated PHR under various EMR systems while keeping the systems, so they are considered a proper alternative. In addition, medical information is more sensitive than other types of personal information, and the blockchain method can settle the issues of security and stability. Therefore, if the PHR is built in a cloud using blockchains, such will pave the way to use the medical information broadly while keeping the current medical systems. Such medical information system will not only have a positive impact on all medical circles but also help provide proper medical service to patients.
2.3 Personal Health Record in the Artificial Intelligence

Medicine is a study on data from its beginning. Traditional medical research methodology has developed in accordance with a hypothesis-based approach.

In other words, it has infinitely repeated a process of resetting hypothesis verification to make a single theory. Those currently conducted as medical service such as diagnosis, administration of medicine, and surgery can all be regarded as the results of such efforts. A medical act that is not based on grounds such as textbook or medical guidelines is actually an illegal medical act. Therefore, doctors do their best to comply with the standards as much as possible. The problem is that there are things that are missing by mistake in the process of diagnosis and treatment of patients, and such little mistakes can even claim the life of a patient in a medical act that is directly connected to life.

Artificial intelligence is a program that uses a medical database containing a huge amount of medical guidelines, so it makes no mistake. Currently, in some specific areas of healthcare, the response of artificial intelligence is the best.

Healthcare is an area with better bibliographic database than that of any other area. In addition, medicine is fundamentally a study about data, being the optimal area in the field of artificial intelligence service using big data.

The reason IBM Watson has selected the genome-related areas with emphasis on oncology among numerous healthcare areas is that the field of oncology has the greatest deal of bibliographic information in the world. The area has enormous carcinogenic genome data including carcinogenic genome map project; even in a day, hundreds of cancer-related papers are published. Thus, the oncology area has well-established guidelines and data for diagnosis and treatment.

The true value that artificial intelligence gives to us lies in the technology for predicting the future health condition of a person through his or her past medical data. Simply predicting the present through past data can be sufficiently done by the present medical technologies without the help of artificial intelligence. As a technology for predicting the future by using past data, machine learning involves the machine’s analysis of training data and big data to learn, just like a person learns something. Here, the machine extracts rules, regulations, expressions, conditions, determination standards, etc. on its own based on huge data, and then accumulates the data in a database for determination.

Here, treatment data and claim data -- which are professional medical records that are some of the past treatment big data on which machine learning is based - are to determine the current illness with past medical history data, so they have limitations.

To apply the artificial intelligence technology to preventive medicine, which is a future prediction area based on data on the patients’ health condition in ordinary times, you must connect and combine PHR -- which is recorded or measured in person by individuals on a life log - and treatment and claim data for pursuing higher value.
03 Blockchain-Based PHR Data Collection via HealthCUBE

3.1 Overview

HealthCUBE is a platform for building a data base of all health records of individuals' whole lives by using personal smart devices. Of those, the key is the sound-based technologies dealing with heart sound and lung sound; additional records are individuals' direct health records including information such as body temperature, blood pressure, blood sugar, oxygen saturation, and ECG along with environmental factors such as temperature, humidity, and positions. We plan to develop HealthCUBE as a platform for recording the health conditions of individuals considering the circumstances that they are living in.

HealthCUBE helps frequently check the health condition of individuals via smart device, which is easily accessible to them, and comprehensively determine their health condition based on the information acquired from various smart devices for healthcare. By recording the health data of individuals from the stage of fetus to that of old age via the HealthCUBE platform, the personal health record for a lifetime can have greater significance from a medical perspective. Especially, human beings are exposed to the danger of various diseases because of innate risk factors due to their genes or posterior impacts owing to environmental elements.

Such danger is sometimes expressed in the family history (those with family history of hypertension or diabetes sometimes need special healthcare more than other people do); if you can monitor a person from a young age, you will be able to predict his or her health condition based on his or her appearance that changes over time. There are average values or statistics on specific diseases but no specific application value for a specific individual, so you cannot say that a general number of cases we talk about may be applied to a specific individual. For instance, a medicine may work for someone but not for somebody else. Likewise, even though the average body temperature of people is 36.5 °C, it does not mean that everyone's average body temperature is 36.5 °C. If someone has a high body temperature since he or she was born, it is not dangerous even if his or her body temperature measures 38 °C. Therefore, it is necessary to observe individuals constantly and closely. In addition, those data that can be objectively determined are very important (of course, the subjective aspects felt by individuals are also important; in medical terms, however, you need objective data for determination). If the method of producing such data is unreasonable, non-medical, or inconsistent, however, the data come to have a problem in reliability, thereby losing its value as data. As such, in some aspects, it is natural that the subject to produce such data is a smart device.

In addition, individuals need to be able to check their own health condition conveniently at home to enable constantly producing data. For instance, most data produced at hospitals are data of the time when the individual is sick (to produce data of the time when an individual is not sick for the prevention or early diagnosis of a disease, a medical checkup is conducted every year or once per specific period of time, but this period can be said to be longer than you may think; you can easily understand what that means by thinking about how many times data are created for a lifetime if the checkup is conducted once a year.), and it is unreasonable to determine such intermittent data as the individual's average data. Therefore, we need healthcare using smart devices that are able to check individuals' health condition including heart sound, lung sound, blood pressure, and diabetes. Accordingly, HealthCUBE aims to collect and analyze various data in the aspect of comprehensive management of PHR and to form a basis for making a comprehensive determination.

HealthCUBE is an individual PHR platform placing special emphasis on the transparent provision of health data by collecting, storing, and analyzing big data by using those medical information devices possessed by individuals, instead of using health data recorded by individuals in person. Especially, we aim to make
HealthCUBE Platform

Directions to Realizing the HealthCUBE Platform

TEAM & PARTNERS

Blockchain-Based PHR Data Collection via HealthCUBE

Issuance and Distribution of Tokens

Legal Considerations and Miscellaneous

Summary

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a platform to apply a key technology and create and provide transparent, trustworthy data based on the data collected by a "smart stethoscope," which enables individuals to measure in person the heart sound, which is the most important among the vital signs that can be collected at home, from among various smart health devices. The area will be expanded from a mere collection of heart sound data to a collection of big data of various bio-signals such as lung sound, body temperature, blood pressure, and blood sugar from cutting-edge personal smart medical devices, thereby laying the foundation for comprehensively determining individuals' health condition.

HealthCUBE aims to serve as a basic platform for primarily helping the underprivileged, those who cannot move about freely or receive medical benefits, those who cannot visit a hospital due to regional limitations, and those in the third world where there are no advanced medical institutions. In addition, the HealthCUBE platform, based on the recognition of the swift development of smart devices that are able to check individuals' health -- following the development of IT devices -- is preparing for such development. Smart devices produce numerous kinds of information, which will be processed individually to build a separate platform. It is not an integrated plan, but a platform will be built to make a business using basic devices that people already have. The HealthCUBE platform is able to accommodate various healthcare devices since expandability has already been considered from the step of planning. We have thought about how to integrate various types of data, to develop them into big data, and to apply artificial intelligence to such.

Not only IT devices but also various industries related to personal health record will develop. For instance, insurance companies are closely related to individuals' health, so they are very much interested in it. When the insured is healthy, the claim for insurance benefit will decrease, which is good for insurance companies. In addition, insurance companies would attempt to find a reliable solution to make the procedure for filing a claim for insurance benefit simpler and to prevent unjust reception of insurance benefit. The most appropriate solution for such purpose is a method using blockchains, and this will be very significant if the HealthCUBE platform develops and an ecosystem is created.

Both direct help from the information produced by smart devices and telemedicine using smart devices will become active. Especially, telemedicine based on quantitative data produced by devices -- which is not a medical examination by interview via a simple video call -- is very significant. Modern medical acts determine the condition of patients based on specific data (measurements/scanned images, etc.). Quantitative data (the information that the body temperature is 38 °C) helps doctors make a precise determination compared to qualitative data (values simply determined personally by individuals, such as the body temperature is high). The higher the precision of smart devices is, the broader the matters that a doctor can determine. When we visit a hospital (in case of a primary treatment institution), we mostly receive a medical examination by interview and come to get a complete medical checkup for measurement when it is determined to be necessary in some cases. The HealthCUBE platform aims to become a data platform that can conduct such prior steps at home.
3.2 Step to Concentrate on Heart Sound (Step 1)

This step concentrates on heart sound related to the health of your heart among various elements that smart devices deal with; this step must have its own integrity since it is not linked to any external data. To this end, various methods are attempted in this step. To evaluate and determine your heart from various angles, you need to obtain heart sound data from diverse aspects. We need data on the various statuses of the heart such as your heart sound when you are in a normal state, when you are exercising, when your exercise is finished, when you have drunk alcoholic beverages, when you are under stress, when you come out from a sauna, when you wake up in the morning, and when you are about to sleep. Especially, even though we also need average values obtained based on big data, a normal range of your own data is more important than a value of any other person. If one has an average body temperature of 35.5 °C, which is lower than that of ordinary people by 1 °C, one feels sick even when one's body temperature is only 37 °C, not even 38 °C. Likewise, in the case of heart sound, you need to accumulate much data to make a more precise determination.

This step is intended to record individuals' heart sound data automatically using a smart stethoscope, which will include the following functions:
3.2.1 Basic Heart Sound Analysis

This is the most basic area of heart sound data analysis, which aims to determine whether the user of the smart stethoscope basically has a heart sound falling within the normal range. This function constantly informs the user whether his or her heart sound shows a high possibility of disorder or falls within the normal range as a result of pattern analysis through machine learning; thus making the user interested in his or her own health.

**Basics of data analysis: (Example) Steps of basic heart sound analysis**

1. **Recruit participants in clinical tests with the smart stethoscope**
2. **Form a standard pattern of abnormal heart sound data based on the smart stethoscope.**
3. **Form a comparative group for normal/abnormal standard patterns via the smart stethoscope.**
4. **Conduct a comparative analysis of the existing clinical data in the medical circles and the data of the smart stethoscope.**
5. **Create feature points.**
6. **Give a reward by Tokens for constantly securing big data.**
7. **Elaborate the results via machine learning.**

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**Measurement**

**Result**

**Record Management**

**Stress Measurement**

**My level:** Measurement

**Average level:** Average of Measurement

**Recommended level:** Recommended level in accordance with age/sex
The basic heart sound analysis method involves performing a comparative analysis of the heart sound data -- which are collected and standardized in advance -- with the heart sound data of the user of the smart stethoscope, to decide the most similar heart sound data and to determine whether they are normal or abnormal by using a control group.

### 3.2.2 Analysis of Resilience from Exercise Load

Your heart performs the same functions as those of other normal people in ordinary times, but it works differently when you do some different action such as walking fast, running, climbing a mountain, and swimming. If a user can be aware of his or her own heart condition in advance, he or she can prevent an accident in advance in many cases.

For instance, if various data are accumulated as to what kinds of changes individuals' hearts experience through exercise by conducting a test before exercise, right after a 30-minute exercise, 10 minutes after exercise, and 20 minutes after exercise via the smart stethoscope, you can recognize up to how much exercise does not take its toll on your heart.

In other words, you can expect the results in advance, so you can deal with them. In the aspect of preventive medicine, very important data will be made. Such exercise science is one of those conducted to be used mainly for improving the exercise abilities of sports players and is not a service or a program that the general public can receive at present. If you use the HealthCUBE platform, however, this can be expanded and applied to the general public.

### 3.2.3 Analysis of Resilience to the Risk Factors of Heart

In general, those acts that strain your heart are made by external factors such as drinking, caffeine intake, and getting on an airplane as well as physical activities such as exercise.

Only a few studies have been sporadically conducted on whether such risk factors do strain your heart or not, and there is almost no study that provides comprehensive determination or specific figures.

In this aspect, you can use the HealthCUBE platform to collect data, use them for your study, and then return the results to individuals. Numerous studies that could not be conducted so far can be performed via the HealthCUBE platform.

### 3.2.4 Data Accumulation via dApp

Data from various smart devices have many issues to be settled with regard to reliability and security for personal information. In addition, to produce various data in great volume, individuals need to make efforts; there must also be compensation as motivation for constant activities. Individuals can steadily produce data for their own health even without such compensation, but the probability that such case would actually happen depends on each individual in many cases. Accordingly, as a way of securing data substantially and constantly through more and more motivation, we are actively considering compensation via a token ecosystem. Next is an actual example of heart sound data developed by a smartphone application before realizing the dApp.
If the dApp is developed, not only security issues but also management labor costs will be reduced. Moreover, since it is a decentralized system, it will become a transparent, reliable system with no suspicion of irregularities. The biggest merit of developing an already developed application such as the dApp may be automatic compensation using a smart contract, auto storage of data, auto reporting after analysis, etc. In addition, you can make compatible businesses by using an ERC20-based token, which is of great help in the formation of the ecosystem. If you provide a basic API to many smart device manufacturers and users transmit data to meet the protocol, they can get compensation.
3.3 Collection of Various Data (Step 2)

3.3.1 Collection of Diverse Bio-Signals

The HealthCUBE platform begins with a smart stethoscope for collecting data of heart sound and lung sound to collect various bio-signals such as body temperature, blood pressure, blood sugar, oxygen saturation, and Lifelong and to evolve into a platform capable of comprehensively determining an individual’s health record.

Along with the development of IoT devices, thanks to the smaller size of sensors and increased precision, the types of data that an individual can measure and collect will increase. Such facts will be of great help in the expansion of the HealthCUBE platform, serving as impetus to make numerous users take part in the ecosystem of the HealthCUBE platform.

3.3.2 Collection of Various Kinds of Environmental Information

Not only those data included in the work of a smart device itself but also those data on the environment of the user will be collected to see what the health condition of the user is like in a comprehensive manner. Environmental data refer to environmental factors that the user was experiencing while measuring the data such as position, altitude, temperature, humidity, and weather. Depending on those factors, individuals’ health condition will differ, so considering such factors other than simple data will play a role as important as that of health data.

For instance, one may have quickened heartbeat when one climbs a mountain, and another may have a disorder in his or her heart in a bathhouse. Likewise, your body reacts to external environmental factors. When such external environmental information is included, the platform can identify risk factors based on a comprehensive determination and inform the user about them to lower the possibility of contracting a disease.

3.3.3 Automatic KYC (Know Your Customer) Using Biometrics

For both medical information and personal health record, proving whose records those are is a very important part. Sometimes, a mistake can be made in entering some measurement data in the name of some other person. This leads to abnormal data when the person’s health condition is determined, so an error in the information will be made. It means that you may make the wrong determination based on incorrect information.

Thus, we have a step for securing the primary reliability of the data measured by individuals, which is KYC. Therefore, just like in KYC on blockchains and KYC in the aspect of devices, collecting biometrics is also an important element. In the aspect of devices, KYC is an easy question if you use the biometrics of individuals.

In other words, for instance, if you attach a finger recognition sensor to the smart stethoscope to have KYC conducted automatically at an auscultation, or if you attach an iris recognition sensor to run KYC automatically, you can leave only your data as PHR on the blockchain, so it will be of great help as well in reducing errors in the data. It is also very encouraging that there are more and more methods for simply conducting KYC thanks to the development of IT and IoT devices.

3.3.4 Personal Health Report

By using big data analysis, machine learning, etc. on the data made by the functions above, we can make a comprehensive report on an individual’s health condition. This report is used only for the individual and is
not an object of transaction. The individual can receive this report on a regular basis and submit the data to a medical institution and take care of his or her own health more precisely.

For the use of the report, we plan to make a web or app services for individuals to use and explain what significance the analysis of the measured data has through the operation of the customer service center. Since all personal records of an individual for a lifetime are stored (technically speaking, it can measure even the heart sound of a fetus, so it is really lifetime), and statistical data can be saved, it can also be of great help in national health management.

### 3.4 Personal Health Record Connected to External Record (Step 3)

The last step is related to personal health record connected to external records -- establishing personal health record mutually connected mainly to the EMR-Tethered PHR. It is a little ideal, but it is also a direction in which all healthcare platforms can proceed.

This step can provide PHR data to medical teams of a specific medical institution by being connected to the electronic medical record of the relevant institution and can let you provide mined data to an external institution, to conduct studies, and to use the measurements in person.

In addition, if you use the HealthCUBE platform as one of the activities of an insurance company to prevent an insured accident, a discount for insurance premium can be provided. This step applies artificial intelligence. From the perspective of insurance companies, it is better to approach the HealthCUBE platform since you can reduce the insurance premium by preventive activities and prevent diseases in advance, instead of constantly giving insurance benefit when the insured contracts a disease. Especially, the HealthCUBE platform provides not only information of the heart and lungs but also various other kinds of personal health information, so insurance companies can prevent insured accidents with a small cost in advance. It has a great merit in the aspect of cost reduction and also serves as a means of preventing a disease from worsening from the perspective of the user.

An artificial program that has learned the huge volume of data collected at this step can report to the user about his or her health condition. A ChatBot also works to respond rapidly to users’ questions even without contacting the customer service center.

Moreover, this step can provide the data measured by smart devices to the data distribution among individuals, medical institutions, and insurance companies based on common data standards, so you need to settle the issue of data standardization first. Ultimately, this is a step of healthcare data integration platform that will evolve into a step of making the data distribution platform and telemedicine available.
4.1 Basic Directions

First, apply blockchain technology to the data created by smart devices to guarantee the data’s reliability and integrity.

The guarantee of reliability and integrity of data in accordance with the application of general blockchain technology is being realized in many areas, and the HealthCUBE platform aims to have a special block chain network structure for optimization.

First of all, to form a private blockchain, make an individual node through authentication by access authority targeting all participants and compose a blockchain network made of only HealthCUBE participants based on Ethereum having a genesis block separated from the existing public Ethereum platform.

In addition, apply a blockchain solution for enterprises to realize the improvement of transaction speed, management of governance of all nodes, etc. Let a specific node perform additional functions such as rapid work proof processing and provision of health data storage as a node for additional functions through the management of governance, and then grant mining rewards accordingly.

Second, ensure transparency and security through the encryption of data and private key signature for personal original data.

All original data of the personal health record must be stored in a storage node through the fragmentation and encryption of the IPFS method of the original data not stored in blockchains other than transaction proofs via blockchains. Here, prove the original files based on the signature of the private key granted to a smart device. In other words, secure transparency by proving the original for all real data.

In addition, randomly fragment all original data, encrypt them, and have them distributed and stored; thus enabling checking only some encrypted data fragments in a specific node for strengthening the security of the data.

Third, apply a distributed data processing technology for efficient storage and safe distribution of large-volume data related to personal health record.

The distributed storage technology of the IPFS method consists of the following: random data fragmentation; encryption; and hash function address connected to them. It is distributed and stored in a network node. All nodes of the HealthCUBE platform allocate some storage space of the relevant node via simple settings. Such nodes become storage nodes to distribute and store personal medical data of the participants in the ecosystem and to receive rewards in return for such.

In addition, the defragmentation of distributed data for safe data distribution can be gathered through authentication, and decoding is available.

Fourth, to enable the HealthCUBE ecosystem, apply access authority management and proper reward compensation system in accordance with the provision of personal medical data.

Personal health information is a very sensitive type of personal information; when the platform develops, and you want to link the information of the HealthCUBE platform and create a third service or realize a function for user convenience in the process, controlling the authority to access the information is a very important issue. Security must be strictly protected, but convenience must be maintained at the same time. It is very ideal, so when we try to realize it in reality, we are expected to face a great deal of actual difficulties. As a solution to that, we aim to form nodes that conduct the management of authority to access. The details will be covered in the Node Composition part of the next chapter.
4.2 Private Blockchain of HealthCUBE Based on Ethereum

HealthCUBE’s private blockchain is based on the existing Ethereum blockchain platform, but it is a separate private blockchain which genesis block is different. In addition, essential functions are added which are necessary for operating a private blockchain such as transaction speed, agreement methods, governance, and closeness between nodes for addressing the shortcomings of a public blockchain.

HealthCUBE is a network with distributed nodes, which are reliable and verified. It consists of the following: a normal node that is an authenticated one; a master node performing a special function; and a participant node that is not authenticated but is able to do a transaction on the HealthCUBE platform.

Normal nodes and master nodes are authenticated nodes. Especially, to register your personal medical data on the blockchain, you must have a normal node qualification. In addition, you can vote for deciding a policy of the HealthCUBE platform, suggest regarding the management of governance, register a smart contract code, and so on.

A master node performs special functions such as processing an approval right after a transaction, providing distributed storage, authenticating a normal node, and so on. A participant node is an unauthenticated node, performing only limited functions. In the step of data distribution, node authentication is not a required matter for an external purchaser wishing to obtain personal medical data. He or she can just do a transaction with HealthCUBE coins but cannot register or change any data.

In case of emergency, an unregistered external medical institution may immediately access via a participant node under the approval and guarantee of a master node. In this case, the authentication is conducted by the multi-sig method. Individuals, groups, etc. with authority to access personal medical information...
such as an authentication key of an individual, that of a medical institution, or that of a government agency participate in the authentication; when there is a specific ratio of authentication, authority to access will be granted. For instance, if there are three individuals/groups with authority for authentication -- which are individual, medical institution, and government agency -- and if the data access authority is granted only when there are authentications by two-thirds of them, and the individual who is unconscious is treated in an emergency room, access to the individual’s personal data will be approved even without the consent of the individual if only the hospital (medical institution) and the government agency perform authentication. Thus, the doctors can perform emergency treatment by reading all medical records of the patient.

4.2.1 Roles of Normal Node and Master Node

The major functions of the HealthCUBE private blockchain are mostly processed by a master node. The smart stethoscope is classified as a normal node, and it mainly transfers the measured heart sound data to the master node via a network. The data will then be proven as the original copy, and membership authentication will be done in accordance with checking the private key of the normal node at the HealthCUBE Interface and will be automatically transferred to the master node.

The master node fragments the relevant data to encrypt them and stores the connection relations of the hash function of each fragment relevant to the address of each fragmented content on the distributed hash ledger. Randomly fragmented hash content is stored in the distributed storage. Here, the distributed storage’s data are not shared by all master nodes.
The node that generates big data related to healthcare including heart sound data is classified as a normal node, whereas the node that approves, distributes, and stores such is classified as a master node. In addition, the participant node will be classified as Guest, which does not go through authentication on a transmission class; the master node will identify the status of the participant node, separately grant authority, and process accordingly. This is aimed at - when an emergency medical matter occurs - immediately transferring the personal medical data of a specific normal node to the relevant participant node.

A master node has server-level hardware with a large capacity of storage. The HealthCUBE Core program for performing additional functions based on the Private Ethereum Core program will be additionally installed on the master node.

1. Application Ledger: Log records and approval/rejection recorded for all transactions conducted on a normal node or the dApp are stored herein.

2. Configuration State: This is a status machine of HealthCUBE, which mainly includes governance (management) settings.

3. Distributed Hash Ledger & Storage: Here is the storage for the distributed storage information of heart sound data and actual data. The hash information of the distributed heart sound data is separately managed in the Distributed Hash Ledger.
The process of processing a transaction of data is as follows:

1. Before sending the transaction, set an authenticated, encrypted network connection via key authentication between a member or a participant and a master node.

2. After that, when the data are received, identify whether the sender is authentic or not, interpret the secret code, and send the information to a private blockchain adapter.

3. The adapter starts a transaction and processes the transaction by the interacting components of a lower-level system of the Ethereum blockchain such as block creation logic and Ethereum virtual machine (EVM).

4. The adapter uses a consensus algorithm to keep all status changes via a network and to store metadata in the distributed ledger.
4.3 Distributed Data Processing of HealthCUBE

4.3.1 Necessity of Distributed Storage

For instance, in case of heart sound data, the size as of the currently measured data is 300 KB (one-time measurement, data of measurement for 20-30 seconds); as the types of measured data increase, and the precision of the sensor grows, however, the size of data will constantly increase. In addition, it is clear that, as the number of times of measurement and the number of users increase, the space needed for storage also increases. Moreover, since these data contain all records of the entire life of an individual, we need to think about the current size and consider the size of storage space to be expanded in the future.

In this connection, it is more reasonable to use distributed storage than a central, expanded storage for the efficiency of search and data. In the case of heart sound data, the collected data will include time of measurement, duration of measurement, types of measurement (general auscultation, stress auscultation, obstetric auscultation, etc.), condition at the time of measurement (normal, after a light exercise, after a hard exercise, after drinking coffee, after drinking alcoholic beverage, after taking medicine, etc.), heart rate, heartbeat regularity, memo, actually recorded heart sound data, etc. In addition, matters such as email address, name, year of birth, sex, whether the patient is an athlete or not, where the patient resides (nation and broad administrative district), height, weight, and data of medical examination by interview will be collected.

All such data cannot be loaded onto a blockchain, and all of them except the basic data come to be stored in distributed storage.

4.3.2 Realization of Distributed Storage Functions

In case of blockchains, the issue of storage has been raised from the early stage. Such is due to the limitations of data that can be put into a blockchain itself. A blockchain has been devised to contain only transaction records, with just a little more space for storing additional data. falsified or not.
The HealthCUBE platform employs the InterPlanetary File System (IPFS) as a data storage method and uses the Merkle Dag for security, which is similar to the Merkle Tree of blockchains. Check the conformity of data from a storage node in charge of distributed storage, go through the process of encryption and division, and then obtain the hash value of the divided data files.

Obtain the root hash of these hash values to record the value on the blockchain. If the divided fragments or the hash values change, they will not be equal to the root hash value, so we can easily see they are falsified.

The distributed storage that the HealthCUBE platform aims to realize encrypts and separates fragments of the data transmitted from a normal node in a master node, distributes and stores based on hash, and stores the root hash in the private Ethereum blockchain ledger.
Data decryption is conducted by a master node. First, the requester obtains the full text of encrypted data and transfers a data decryption request signed by a private key to the master node. The master node then checks the identity based on the electronic signature of the requester and transfers a data release key encrypted by the public key of the requester.

The requester extracts the data release key with his or her private key and decrypts the data.

### 4.4 Data Analysis: Artificial Intelligence (AI) Analysis

#### 4.4.1 Machine Learning (Applied to Step 1 of the Platform)

The types of devices and data applied to the platform are expected to increase constantly in accordance with the expansion of business models. Here, we aim to explain about machine learning on heart sound data applied as the first device among those.

An analysis of heart sound data in the early stage focuses on pattern analysis. After analysis of a huge number of sample data, an environment will be prepared for determining the rules, regulations, expressions, conditions, determination standards, etc. on the machine’s own, and those will be accumulated...
on a DB to make the machine learn them to calculate basic information. In other words, it is intended to accomplish the primary goal of the user (to obtain the information on the user's current health condition) via HealthCUBE through a relatively simple machine learning process. To this end, data will be collected by a machine learning process through supervised learning. As basic data, blank data is planned to be generated by gathering healthy male and female participants by age, and data will be generated by gathering participants with history of heart disease. In this connection, an analysis process will be conducted; as the participants increase, the determination will become more accurate. In this regard, time, cost and participants are important items.

To check the health condition of a user via the data provided by the user, we extract characteristic patterns from the data generated by using the control group as above, increase the significance in determining the health condition of the individual by using statistics, and determine via machine learning.

**4.4.2 Application of AI for Heart Sound Data (Applied to Step 1 of the Platform)**

To process data more precisely, we must go through a specific analysis process as follows: Beyond simple machine learning, we plan to apply a deep neural network (deep learning technology for high accuracy of heart sound data), and the study is currently underway.

### Sound Features

**A. TIME DOMAIN**

The time axis plays an important role. Specifically, it is the interval between inhalation and exhalation.

**B. FREQUENCY DOMAIN**

Frequency range (range of the number of vibrations), power spectral density (degree of integration-density of a heart sound graph)

**C. WAVELET TRANSFORMATION COEFFICIENTS**

Vibration translation coefficients (the heart sound's basic waveform has vibrations or waves like a wave having an amplitude that repeats increasing and decreasing up and down centering on 0)
Heart Sound Classification

Based on data (volume of 2,000 units of data of 20-30 seconds) of M. general hospital in the US, classify the heart sound data by neural network learning. Neural network learning is a method of letting a machine calculate a feature value of things on its own by learning by itself.

D. DECOMPOSITIONS
(homomorphic envelops and eigen vectors)

E. ENTROPIES $M \omega^2 A^2$
It means energy. $P = (1/2) \mu v \omega^2 A^2$
When a wave function is given, an energy of wave per unit length is calculated as a function of position and time. $P$: Intensity of wave, $A$: Amplitude, $v$: Velocity

F. ANALYSIS OF APPROXIMATELY 50 OTHER FEATURES OF HEART SOUND
A mixed method of supervised/unsupervised learning First, let it learn a feature value of heart sound data of a sample population by supervised learning. After that, constantly add sample data to let it repeat learning via enormous training data and to provide a high-level result of comparative analysis for heart sound data.

[Diagram of Working flow in 50 features]

Raw data ➔ Pre-Processing

- Time-domain features
- Frequency-domain features
- Wavelet features
- Various decompositions
- Various entropies

Features Fusion

Train ANN in an iterative way

Classify recording using trained weights of neurons in ANN

[Neural Network Training]
4.5 Data Processing

4.5.1 Data Security

Dissemination of Exclusive Viewer for Data

To protect data, various methods can be used. Among those, the most definite method developed so far is to approach via a viewer exclusively for data. This viewer is developed as an exclusive application, and it also employs an exclusive protocol as a communication method. By selecting an exclusive protocol, it can rapidly and actively deal with any security issue that may arise in the future. If we use a general-purpose protocol or a known protocol, the enclosedness will decrease, and security will weaken as well. The exclusive protocol here does not refer only to the protocol itself but includes various accompanying security programs (DRM, keyboard security program, memory hacking prevention tool, etc.).

Data Storage

Typical medical information encryption process uses an encryption key, as you can see in the figure below, to encrypt data, and store the data in the secure storage.

The method above is optimized for central management, but it must be optimized to use the distributed storage method in the distributed environment such as blockchains. Therefore, this project has planned to employ the IPFS, which has the most excellent security and superior performance among the currently existing distribution and storage methods.

The function required by the HealthCUBE platform is a safer storage method and is designed to take out data. To this end, a side chain divides the functions of a master node for each authority to entrust, authenticate, and store them. After the master node performs encryption, the encrypted content gets divided into several fragments and makes a hash of each fragment. Then, it makes a root hash of those hashes and stores it on the blockchain.

Here, what is used is the Merkle Dag method, which is security (security of integrity) used by most blockchain systems such as the Bitcoin. (See item 3.3.2.)
4.5.2 Classification of Identified/Unidentified Data

Those data based on medical information all include sensitive information; thus, in principle, all of them must be unidentified, leaving only an identifiable clue. Leaving identifiable information open in each piece of data is risky, yet storing each piece of data with a unique identification number assigned by a hospital to each individual is also problematic. This unique identification number must also be encrypted or tokenized and stored. Even the token must be masked in accordance with the usage.

4.5.3 Data Access Authority Management

Medical information includes data collected by medical acts and analysis data based on such data. It refers to information on patients’ health condition collected in all processes of medical acts including diagnoses, treatment, and observation of prognosis after treatment. This medical information is very sensitive private information. The information’s confidentiality must be strictly assured, and the supervision and management of all individuals, institutions, etc. accessing the information must be thoroughly carried out as well. In addition, those demands for rapid processing - which is a unique characteristic of medical institutions such as emergency room -- must be met. To this end, it is essential to prepare a plan for granting access authority by step and to manage it. First of all, access authority is largely divided into four steps.

**Step 1: Search of unidentified information**

For data distribution, search is an essential element. Search is a type of data that does not have to contain personal information, so it just needs to contain the summary, features, and indexing information. If you want more details, you can proceed with the authentication process as another step.

**Step 2: Detailed search of unidentified information**

A detailed search means that you need to search some more important information. This can be interpreted to mean that you want to access more sensitive information among personal information. To obtain such information, you need to conduct not only an authentication of the institution where you want to search (this is already done in Step 1) but also an authentication of the searcher (an authentication on who attempts to access for what purpose). Through this process, you can reduce the probability of information being leaked via illegal elements or unnecessary search.

This step does not provide identification information.

**Step 3: Detailed search of identified information/access to data by medical institution**

Access to data by a medical institution must be done at very high speed. With regard to such access, the top priority is placed on the transaction speed based on the justification that you need to be able to view the identified information. In other words, it means that a fast access track must be separately formed. The same goes for general outpatient treatment; in an emergency, however, if you fail to acquire information rapidly, the limitations of the provided information will be revealed. Therefore, in the aspect of use of information, this is the most important part among the four steps of access authority. To this end, the design must be executed to acquire an authority to be attached to the side chain network (private blockchain) right away on the blockchain. In other words, in those areas dealing with general medical information, public blockchains are not preferred; private blockchains, which are safer, are preferred. In the case of HealthCUBE blockchains, the private blockchain supervises all data, so it enables medical institutions to access the blockchain directly and to acquire authority, thereby fulfilling the purpose above. This part can be implemented through a master node on the private blockchain.

**Step 4: Data distribution between parties of distribution of medical information**

In the distribution of medical information, only in the aspect of using statistics and data, excluding cases of
distribution including personal identification information, do all data that do not identify individuals become the object of distribution. When it is significant only when data are distributed including personal information, however, the transfer must be conducted only after each and every individual personally gives his or her consent. To this end, the purchasers of data come to request for approval for the transaction as a group to the owner of the data they want to get. On the blockchain, if approval is given after a transaction requesting for approval is automatically generated for each individual, it must be allowed to reflect the completion of transaction to the purchaser and to acquire authority to access data at the same time. This can be realized by a smart contract, for which you can acquire permission on the main network.

4.5.4 Data Standardization

The biggest obstacle in the exchange and distribution of medical information is legislation and standards. Since hospitals and medical devices use different standards, it is not easy to exchange information, and there may be different opinions in interpreting measurement data. Accordingly, the movement for the standardization of medical information data has been active so far. This movement is active in foreign countries as well as in the Republic of Korea. In the US, six companies (Google, Microsoft, Salesforce, Amazon, IBM, and Oracle) agreed to introduce interoperability technologies for healthcare to be realized via cloud and artificial intelligence that provide medicine customized to the health condition of individuals by connecting isolated data to each individual medical institution.

Despite such endeavor, having all medical data standardized and used for industries is expected to take a long time. Therefore, the data we aim to realize first are heart sound data, which has no digitalized standard so talking about any standard is impossible. In other words, only when big data are made by collecting heart sound data and when analysis by artificial intelligence is made possible based on such data can you distinguish valid digital data (features data that are significant digital data and which must be measured) from insignificant data; in this status, you are deemed able to standardize heart sound data. In addition, it is expected that, as more elaborate, more abundant data are generated by the development and spread of devices, you can accomplish substantial standardization beyond standardization for consultation.

Here, the HealthCUBE platform aims to promote the rapid application of artificial intelligence for the standardization of heart sound data, to select data through that, and to perform the basic work for standardization; thus completing the standardization by connecting to clinical data.
The second standardization is standardization for data distribution. Data distribution means the standard for data provided to various institutions, so the data must meet the standard format to link with the format (this format is deemed diverse in general) of institutions requesting (or purchasing) medical information. This can be called data protocol beyond communication protocol. In other words, under the premise that data standardization has been completed, another goal is to determine a protocol to determine how to transfer the desired data to each institution. To this end, making a structure that is acceptable to every institution is the best way; assuming that not all institutions meet this demand, however, we are planning to build API application servers (data gateway).

* This matter (data standardization) is necessary in Step 3, which is to realize the HealthCUBE platform requiring data distribution. To meet such standard in this step, we can compose a consultative group including all parties such as medical institutions in the Republic of Korea or observe the international standards (see the Appendix).

### 4.6 Token Ecosystem

#### 4.6.1 Overview

Blockchains become stronger and safer as the number of users increases. Blockchains’ ecosystem becomes more active as more people use it. In the HealthCUBE platform, users play the biggest role in the ecosystem. In other words, the users are the subject of data generation, and they will become the subject of data consumption from here on. The PHR generated by various smart devices gets transferred to a master node after data are generated and comes to receive compensation via the HealthCUBE tokens when it is loaded on a blockchain.

Other than compensation for blockchains, an analysis of health condition or patterns related to health is conducted via big data, machine learning, artificial intelligence, etc. based on the data provided by the user, with an analysis report submitted every cycle. Through this, the user can become interested in and manage his or her health, so it will be of help for preventive medicine as well.

In addition, the provided data are gathered for use as basic data for the analysis of big data to be used not only for the HealthCUBE platform but also for various medical institutions and the development of
medicine. In this process, medical institutions or pharmaceutical companies may purchase the data with the tokens, and part of the data is used for the maintenance and technological development of the HealthCUBE platform. Most of the money used to purchase the data will be returned to the user who provided the information; when the data standardization is well-accomplished, and data are actively shared, individuals' medical records can also be contained in the blockchain ecosystem.

HealthCUBE generates a certain ratio of coins for compensation as donation points and accumulates them. Such donation points will be converted into coins to be used for supplying smart devices to consumers in the third world -- which is a blind spot for medical service -- and granting an opportunity to receive the medical service benefits provided by the HealthCUBE platform. In addition, opportunities can be created for the users to be members of HealthCUBE by the benefits to generate income by actively contributing to the ecosystem.

In this process, it is most important to manage transparently whether the donated tokens are transferred and used correctly. To prove this, the concept and technology of blockchains are used.

4.6.2 Ecosystem Members

The members of the ecosystem are largely divided into PHR producers, PHR consumers, and PHR verifiers.

1. PHR producers: As the subject of quantitative big data production by medical devices, they register smart stethoscopes for extracting the basic heart sound data and additional personal medical devices on the HealthCUBE platform, thereby producing big data. The PHR is divided into heart sound PHR, blood sugar PHR, and environmental PHR.

2. PHR Consumers: PHR consumers are data consumers who check and process the personal medicine-related data collected; at the same time, they are issuers of HealthCUBE tokens. Here, PHR producers -- to produce big data and at the same time check their own data -- need one HealthCUBE token per megabyte of data to be checked.
Besides, to check and process big data, medical institutions and companies need to purchase HealthCUBE tokens.

**PHR verifier:** PHR verifiers are the subject of private blockchains to verify big data transactions for maintaining a stable HealthCUBE token ecosystem, to encrypt big data, and to distribute and store big data. To become a PHR verifier, we must have a certain quantity of HealthCUBE coins for the purpose of early guarantee; these are used as funds for compensating PHR producers in the early stage.

### 4.6.3 Cryptocurrency for Maintaining the Ecosystem

To maintain the HealthCUBE ecosystem consisting of voluntary participants, two security-type coins are necessary. To operate a stable HealthCUBE blockchain, we need HealthCUBE coins — which are coins for guaranteeing a master node — and HealthCUBE tokens, which are used for internal transactions involving big data. In other words, it is necessary to separate coins for guarantee from tokens for internal currency.

---

**HC Coin [HCC]**

**Coins for Guarantee**

1. Coins that can be traded on the exchange
2. Used as a warranty coin to become a master node

**HC Token [HCT]**

**Tokens for internal currency**

1. The Tokens are currency for internal transactions, and play a similar role to that of the existing points
2. 1 HC is fixed as 1 HCT
3. The HCT can be traded only within the HealthCUBE blockchain.
Out of the 5 billion tokens (Symbol: HCC) issued, 1.75 billion tokens accounting for 35% of the total tokens are planned to be issued through IEO.

**Total Number of Tokens Issued: 5 billion tokens (100%)**

**IEO: 1.75 billion tokens (35%)**
Reserve: 1.75 billion tokens (35%)
Founding Team & Advisors: 1 billion tokens (20%)
Business Development: 0.5 billion tokens (10%)

60% out of remaining 65% shall be locked up for one year from IEO commencement date.
(Balance 5%: reserve fund for platform development)

1️⃣ 1 year Lock-up for 60% shall be released in 10% increments for 10 months after the lock-up period.

2️⃣ The IEO sales volume of 35% shall be traded on the coin exchanges in the following order.
   - A. 30%: Available immediately after listing
   - B. 30%: Available from 30 days after listing date
   - C. 40%: Available from 60 days after listing date

*Token distribution policy to protect IEO Participants' investment value by sequential trading distribution*

Of the funds procured through IEO, 50% will be used for business development, with an appropriate budget to be distributed for items required for business development.
TEAM & PARTNER

TEAM

Management Team

- COO/CFO, Smartsound Corporation
- VP, KT Corporation Global BG
- Director, KT Corporation Strategic Investment
- Manager, Daewoo Int'l(America), NJ
- Manager, Daewoo Corporation
- MBA, USC(Marshall School of Business)
- BA, Korea University
- 24 y ears Experiences in Global Business Strategy Planning / Development / Investment / Management

- CSO, Manchan Lee
- 2 Start-up Experiences
  - CEO, Global CyberMone y Co.,Ltd & Ovtyz Co.,Ltd.
  - Samsung SDS(16years)
- 30 + years Experience in IT industry
  - The First Mobile Middleware Commercialization in Korea
  - The First Mobile Platform(JVM) Development in Korea

- Founder, Woojun Lee
- Auditor General, Smartsound Corporation
- CEO, Three Family Co. (China)
- NHN in China
- BA, Peking University in China
- 6 years Experiences in Overseas Business Development

- CTO, Jaeyong Kim
- Director, Datastreams Co.
- Director, KK Protech Corporation
- Director, SR Commerce Corporation
- Co-Founder, Crosswork Corporation
- MS, Sungkyunkwan University (Industrial engineering)
- 24 years Experiences in Information System Consulting, Technical Planning & PM
## Developer (Business, Blockchain, SW, HW, Rule Engine)

<table>
<thead>
<tr>
<th>Developer</th>
<th>Profile</th>
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<tbody>
<tr>
<td><strong>Global Biz</strong></td>
<td>Lee, Jungho</td>
</tr>
<tr>
<td>CEO, Smartsound Corporation</td>
<td></td>
</tr>
<tr>
<td>Rentalscars.com in UK</td>
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<tr>
<td>BA, Tsinghua University in China</td>
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<tr>
<td>4 years Experiences in Overseas Business Development</td>
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<tr>
<td><strong>Blockchain Architecture</strong></td>
<td>Yoon, Seokbin</td>
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<tr>
<td>Senior Consultant, D’LIGHT Law Group</td>
<td></td>
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<tr>
<td>Chairman, Open Blockchain Forum</td>
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<tr>
<td>Oracle Korea, IBM Korea, Epson Korea</td>
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<tr>
<td>BS, Sogang University (Chemical Engineering)</td>
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<tr>
<td>22 years Experiences in IT Industry</td>
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<tr>
<td><strong>Smart Algorithm</strong></td>
<td>Song, Youngmin</td>
</tr>
<tr>
<td>R&amp;D TeamLeader, Smartsound Corporation,</td>
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<tr>
<td>S/W TeamLeader, Borasys., Inc.</td>
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<tr>
<td>Asiana IDT Home Network Team</td>
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<tr>
<td>Senior Researcher, TJ Media, Institute of Technology</td>
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<td>Samsung SDS</td>
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<tr>
<td>MS, Korea University (Electronic Engineering)</td>
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<tr>
<td>BS, Korea University (Electronic Engineering)</td>
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<tr>
<td>18 years Experiences in S/W development &amp; Technical Planning</td>
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<tr>
<td><strong>Smart Device</strong></td>
<td>Kim, Joohak</td>
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<td>CTO, Smartsound Corporation</td>
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<tr>
<td>VP, New Business Project Team, SiliconLab Co., Ltd.</td>
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<tr>
<td>Chief Engineer, AtLab Co., Ltd.</td>
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<tr>
<td>General Manger, LSI Dept., Samsung Electronics Co.</td>
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<td>Image Development Team, Samsung Electronics Co.</td>
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<tr>
<td>BS, Korea National Open University, Computer Engineering</td>
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<tr>
<td>30+ years Experiences in Audio Circuit Design &amp; Semiconductor Application Technology</td>
<td></td>
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<tr>
<td><strong>Smart Application</strong></td>
<td>Hwang, Banseok</td>
</tr>
<tr>
<td>S/W Team Leader, Smartsound Corporation</td>
<td></td>
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<tr>
<td>Director, TrendyApp Co.</td>
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<tr>
<td>BS, Hanyang University (Computer Engineering)</td>
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<td>Translation publications (10 Technical Books)</td>
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<tr>
<td>17 years Experience in S/W Development</td>
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TEAM & PARTNERS

• Director, Product Technology Center, Innorules Co., Ltd.
• Chief Researcher, Innoexpert Co., Ltd.
• Manager, H&K Co., Ltd.
• Hyundai Information Technology Co.
• MA, Business Information, Kookmin University
• 16 years Experiences in Development of Rule Engine system

ADVISOR

• Heart Hospital, Asan Medical Center Director, Valve Disease Center / Lung Hypertension Phlebothrombosis Center
• Professor, Department of Cardiology, College of Medicine, University of Ulsan
• The Cleveland Clinic Foundation
• BS, MS, MD, Seoul National University

• Department of Cardiology, Sejong Hospital, Manager of Treatment Department
• Full-time doctor, Korea University Medical Center
• Completed the doctor’s course at the Graduate School of the College of Medicine, Korea University.
• MS, Graduate School, College of Medicine, Korea University
• BS, College of Medicine, Korea University

• Professor, Department of Obstetrics and gynecology, College of Medicine, Korea University
• Department of Obstetrics / Gynecology, Ewha Women’s University, Clinical Professor
• 2012 Korean Society of Maternal Fetal Medicine - First Prize
• Korean Society of Obstetrics and Gynecology, Managing Editor
• Medical School, Harvard University, Exchange Professor, Research Lecturer
• MD, College of Medicine, Korea University
<table>
<thead>
<tr>
<th>TEAM &amp; PARTNERS</th>
<th></th>
<th></th>
</tr>
</thead>
</table>
| **Blockchain Expert** | **Richard Noh** | • CEO, Blockcast Co.  
• CEO, DNIB  
• Member of National R&D Task Selection and Evaluation Committee, KCA (Korea Communications Agency)  
• BS/MS, Seoul National University |
| **Industry Expert** | **Sohn, Weeyong (William)** | • CEO, Atlasward Co., Ltd.  
• CEO, Genesis Partners  
• Consultant, A.T. Kearney  
• MBA, University of Michigan (Ann Arbor)  
• 20+ years Experiences in Global Marketing & Management Consulting |
| **Industry Expert** | **Eom, Jootae** | • CEO, Kongkwan Protech Co., Lt  
• CTO, Kongkwan Corporation  
• Daewoo Engineering  
• MS, KAIST (Industrial Engineering), BS, Seoul National University (Industrial Engineering)  
• 30-year career in IT |
| **Industry Expert** | **Im, Ilkyun** | • Interdisciplinary Professor, Institute for Convergence, Sunkyunkwan University  
• Executive Director, Data Streams Corp.  
• Big Data Business Department Principal, Samsung SDS Corp.  
• Public Business Department, LG CNS Corp.  
• PhD, Sungkyunkwan University (Electronic and Electrical Engineering) |
| **Industry Expert** | **Koh, Jongkwan** | • Director, Medical & Pharm Department, Newsworks  
• Korean Medical Association Senior Club Steering Committee Member  
• Invited Professor, Department of Healthcare Management, Gachon University  
• CEO, Joongangilbo Healthmedia & Director, JMPlus Content Sector  
• PhD, Graduate School of Public Health, Gachon University |
• Principal Researcher, ADD  
• Logistics System Division Director / C4I General Manager, KIDA / IDIS  
• Adjunct Professor, Graduate School of Kongju National University  
• Adjunct Professor, Graduate School of Information Sciences, Soongsil University,  
• PhD., Illinois Institute of Technology, US (Engineering)

• CEO, Smartcontentshub Co.  
• CEO, Solbrain Co.  
• VP, Ovytz Co.  
• Strategy Planning Dept. Samsung Electronics  
• MS, Kyunghee University (IT)
08 Legal Considerations and Miscellaneous

The HealthCUBE White Paper is prepared to make a document of and deliver the overall business plan for the project and shall not be used for recommending a specific investment, etc. In case using the information in this White Paper causes damage, loss, liabilities, or other financial damage, HealthCUBE shall not indemnify, compensate, or take responsibility for such. The contents of this White Paper shall not be regarded as inducement or recommendation to engage in investment activities. Any person who refers to this White Paper shall carefully consider and review all risks related to cryptocurrency, IEO, and other related business activities. We do not provide any guarantee to or assume responsibility for the target who refers to this White Paper.

Risk Statement

All HealthCUBE cryptocurrencies circulated before the HealthCUBE COINs are issued shall be traded as TOKENs. The regulatory authorities have not reviewed or approved the information specified in this White Paper. Such actions have not been and will not be taken according to the laws, regulatory requirements, or rules of the jurisdiction. The publication, distribution, or dissemination of the White Paper does not mean that the related laws on the right of jurisdiction, regulatory requirements, or rules have been observed. Within the maximum limit permitted by the relevant laws, regulations, and rules, the distributor and its affiliated companies, executives, staff or agents, coins, and related products and services do not assume responsibility for any and all types of damages including direct, resultant, subordinate, special, or indirect damages (including income loss, sales loss, and other damages without being limited to them).

Terms & Conditions

The cryptocurrency coins shall not be regarded as an investment but may obtain value over time. In addition, when the solutions implemented by HealthCUBE are not actively used in actual society, the value may decrease.

Risk of loss of funds: The funds recollected during an IEO procedure shall not be guaranteed. When the value is damaged or lost, there is no individual or public insurance agent that can compensate the purchaser. Risk of failure: In the funds collected during an IEO procedure, the various risks that can occur in business as well as at other enterprises, such as failure of the HealthCUBE COIN business and all subsequent marketing activities, fall under this case as well.

A technological innovation such as the development of a quantum computer is likely to pose a risk to cryptocurrency communication including the HealthCUBE COINs. When a situation preventing the use of HealthCUBE COINs due to exemption from the responsibility of guarantee or any other various causes arises, the purchaser himself or herself shall assume responsibility for the loss, and HealthCUBE shall not be liable to the parties concerned. After the date of issuance, the HealthCUBE COINs shall be transmitted to the parties concerned who have bought the COINs without infringing any other person's intellectual property rights and without any explicit or implicit guarantee. Some jurisdictions do not acknowledge the exemption of implicit guarantee; thus, the aforesaid exemption of implicit guarantee is sometimes not applied.
A. What Is Heart Sound?

Heart diseases are considered a major cause of death in most countries. According to an announcement of the World Health Organization (WHO), the No.1 cause of death across the world is ischemic heart disease. In the top 10 countries with the biggest income, ischemic heart disease is found to be the biggest cause of death, with stroke a distant No.2.

The same is true in the Republic of Korea. In the announcement by Statistics Korea in 2017, heart disease was found to be the second biggest cause of death, following cancer in first place. Heart disease also showed a steady increase.
Accordingly, many diagnosis tools have been developed to evaluate rapidly and precisely the condition of your heart and diagnose the disease. Among those, a fast, economical method is "auscultation" to listen to the heart sound and analyze it for the evaluation of your heart condition. Since René-Théophile-Hyacinthe Laennec (1781-1826), who was a physician in France, invented the stethoscope with a simple structure, which is made of an empty wooden pipe 9 inches long and 1 inch in diameter, the auscultation of heart sound has become one of the very important methods for diagnosing heart diseases. It has also developed as a study (phonocardiology).

Your heart has four valves, which are: the bicuspid valve between the left atrium and the left ventricle; the tricuspid valve between the right atrium and the right ventricle; the aortic valve between the left ventricle and the aorta; and the pulmonary valve between the right ventricle and the pulmonary artery. Heart sound is a sound generated by the flow of blood and the opening/closing of the valves of the heart in accordance with the contraction and relaxation of heart muscles, and it consists of four sounds (S1, S2, S3, S4).

The first sound, S1, is a sound of "lub" in the early stage of the systole of the ventricles of the heart; it is made by closing the tricuspid valve and the bicuspid valve. It is low and dull, and it persists for a relatively long time. S2, the sound of "dub" in the early stage of the diastole of the ventricles of the heart, is made by closing the aortic valve and the pulmonary valve. High and sharp, it persists for a short time. S3 is a sound that is heard right after S2. It is made when the blood flow introduced as the bicuspid valve is opened collides with the ventricular wall. S3 is a low sound that persists for a short time, so it is hard to auscultate. It can be auscultated when you have any of various diseases, but it may also be heard in children, pregnant women, or athletes with normal heart function. S4 is a sound made when blood flow is introduced into the left ventricle due to the contraction of the atriums at the end of the diastole. It can be heard right before S1. Mostly, however, it is hard to hear by a stethoscope. It is related to diseases in many cases. In addition, when there is a structural problem in your heart, such as a valvular disease, turbulence of blood flow occurs in the heart. Its sound is called cardiac murmur, which also serves as a good indicator for determining whether there is a disease in the heart or not. Cardiac murmur shows characteristic aspects in accordance with the cause. During an auscultation, the doctor identifies the form of heart sound and cardiac murmur to use it as the standards for identifying the status of the heart and determining if the heart has a disease or not.
The method of evaluating the heart condition by auscultating the heart sound and cardiac murmur mostly uses $S_1$ and $S_2$ as the reference point and conducts the evaluation by identifying the size of $S_1$ and $S_2$, the point of time when cardiac murmur occurs, the strength and aspects of cardiac murmur, etc. In general, it is not easy to identify and diagnose the aspects of such sound during a short cardiac cycle of less than 0.8 seconds.

To make a precise diagnosis through auscultation, you need a long process of training as well as lots of experiences. In addition, there are great differences in auscultation ability between doctors. Even a much experienced cardiologist has to depend on his or her sense while doing auscultation. Thus, traditional auscultation using a stethoscope lacks reliability. In addition, nowadays, there are more and more doctors who are not used to a stethoscope, so large hospitals and clinics specializing in the heart gradually come to depend on the expensive echocardiogram; hence the growing medical costs for patients. As such, heart sound analysis is attracting attention again due to its low cost and simple process. The phonocardiogram is an examination method of visualizing the heart sound acquired by a high-performance microphone by converting the sound into a visual wavelet. Since it does not use contrast medium or radiation, it has the merits of auscultation, which is not hazardous to the human body and inflicts no pain while being able to perform objective, detailed analysis and record the results, which the existing auscultation could hardly do.

Especially, thanks to the development of the electronic stethoscope and the advancement of computer-assisted auscultation, it has become possible to digitalize a phonocardiogram for recording and analysis. Thus, this is used in various areas such as training for doctors as well as treatment of patients. On top of that, with the recent dissemination of smartphones and wearable devices, its scope of application is expanding even to the monitoring of healthy people’s heart condition as well as that of patients.
Appendix

B. Significance of Heart Sound Big Data, Machine Learning, and AI

In general, a heart sound data analysis goes through the process of acquiring pure heart sound excluding cardiac murmur (denoising) and process of precisely dividing the acquired heart sound (segmentation). Through these processes, you come to identify precisely the systole and the diastole, analyze the time area and the frequency area of heart sound data, and determine whether the heart sound is normal or not.

Already from around 50 years ago up until now, a number of heart sound analysis studies have been conducted. Until relatively recently, studies have been conducted by analyzing the heart sound using various algorithms and statistical models and the analysis for diagnosing diseases. Since Gerbarg, et al used an automatic heart disease exploration algorithm using the threshold-based method and published a study to select children with rheumatic heart disease in 1963, relatively recently, in 2007, El-Segaier, et al used a stepwise logistic regression analysis and reported how to distinguish normal heart sound from abnormal heart sound effectively. Nonetheless, studies so far have targeted only a few heart sounds selected by the researchers; the diagnosis models were limited, and they could be used only for clean data without noise. Accordingly, the existing analysis method has clear limitations to be used for selective examinations on various diseases in clinical settings or to be used by healthy ordinary people in non-clinical settings.

Therefore, nowadays, there are active attempts to overcome the limitations of heart sound analysis using the existing method by introducing the rapidly developing computer science and artificial intelligence to heart sound analysis and analyzing the heart sound with algorithms based on machine learning such as K-nearest neighbor (K-NN), artificial neural network (ANN), and support vector machine (SVM). Especially, the deep learning technology -- which places an artificial neural network made by imitating the information processing process of the human brain, which conducts complex calculations, etc. with several neurons connecting to each other in multiple layers and lets the machine learn an automated classification method -- has areas of application that are rapidly expanding as the calculation using the graphics processing unit (GPU) develops. Such deep learning algorithm is able to extract and train features from data, so it can be used for signal data, etc., which are hardly detected directly by human beings or which have an unclear causal relationship. A heart sound obtained from various environments can be said to be appropriate for analyzing the features of data and evaluating the heart condition. So far, the following heart sound analysis studies using such artificial intelligence have been conducted:
### Appendix

<table>
<thead>
<tr>
<th>Author, Year of Publication</th>
<th>Data Set</th>
<th>Technologies Used</th>
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<tbody>
<tr>
<td>Reed, et al, 2004</td>
<td>5 different normal and abnormal PCGs</td>
<td>ANN</td>
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<td>Gupta, et al, 2006</td>
<td>41 PCG from Singapore General Hospital</td>
<td>MLBP-NN, GAL</td>
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<td>Dokur and Olmez, 2008</td>
<td>14 different PCG signals</td>
<td>Kohonen’s ISOM Incremental ANN</td>
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<td>Jaramillo-Garzon et al, 2008</td>
<td>16 normal PCG signals and 6 signals with murmurs</td>
<td>KNN classifier</td>
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<td>Ari and Saha, 2009</td>
<td>104 PCG signals provided by the Maulana Azad Medical Institute</td>
<td>ANN</td>
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<td>Bunluechokchai and Ussawawongaraya, 2009</td>
<td>Normal and MR signals</td>
<td>Local intermittency factor</td>
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<tr>
<td>Wen-Chung and Chih-Chao, 2011</td>
<td>44 PCG signals from Texas laboratory</td>
<td>SVM+adaptive feature selection</td>
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<td>Phanphaisam, et al, 2011</td>
<td>80 PCG signals</td>
<td>ANN</td>
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<td>Liu, et al, 2012</td>
<td>270 PCG signals: 104 normal and 166 abnormal</td>
<td>SVM</td>
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<td>Safara, et al, 2013</td>
<td>59 PCG signals: 16 normal and 43 abnormal</td>
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<td>Amiri and Armano, 2013</td>
<td>110 normal and abnormal PCG signals</td>
<td>Regression tree</td>
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<td>Roy and Armano, 2014</td>
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<td>KNN</td>
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<td>Farzam and Jalil, 2014</td>
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<td>Guillermo, et al, 2014</td>
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<td>Feed-forward ANN</td>
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<td>SVM modified cuckoo search algorithm</td>
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<td>Shivnarayan, et al, 2015</td>
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<td>SVM</td>
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<td>KOCYIGIT, 2016</td>
<td>14 different PCG signals</td>
<td>SVM, linear discriminant analysis and naive Bayes classifier</td>
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<td>Harfash, 2016</td>
<td>-</td>
<td>Eigenvectors</td>
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<tr>
<td>Imani and Hassan, 2016</td>
<td>98 PCG signals: 40 normal PCG signals and 58 abnormal PCG signals</td>
<td>Maximum likelihood classifier with Gaussian distribution SVM with polynomial kernel</td>
</tr>
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</table>

C. Medical Information Processing Guidelines  
(Republic of Korea)

If there are special regulations related to the processing of personal information of patients, medical professionals, and staff in any other laws and ordinances that regulate personal information processing in medical institutions, such laws and ordinances shall be preferentially applied. If there are none, the Personal Information Protection Act shall be applied.

If there are regulations on personal information protection in the "Medical Service Act," the Medical Service Act shall be preferentially applied. Otherwise, the "Personal Information Protection Act" shall be applied. Medical institutions may collect unique identification information and sensitive information for the purpose of treatment according to laws and ordinances and may use the information for purposes of treatment. Various personal information files include unique identification information including the resident registration number and various kinds of sensitive information.

Unique identification information: Resident registration number, driver's license number, passport number, foreigner registration number.

Sensitive information: Ideas, beliefs, joining/leaving a labor union/political party, political opinions, information on health, sex life, etc., genetic information, criminal record, etc.

<table>
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<tr>
<th>Personal Information File Name</th>
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<tr>
<td>Treatment Request</td>
<td>Article 22 of the Medical Service Act</td>
</tr>
<tr>
<td>Physician Surcharge Request</td>
<td>Article 46 of the Medical Service Act, Article 2 of the Rules on Physician Surcharge</td>
</tr>
<tr>
<td>Treatment Record</td>
<td>Article 22 of the Medical Service Act, Article 14 of the Rules on Physician Surcharge</td>
</tr>
<tr>
<td>Premature Birth Record</td>
<td>Article 22 of the Medical Service Act, Article 14 of the Rules on Physician Surcharge</td>
</tr>
<tr>
<td>Nursing Record</td>
<td>Article 22 of the Medical Service Act, Article 14 of the Rules on Physician Surcharge</td>
</tr>
<tr>
<td>Patient List</td>
<td>Article 22 of the Medical Service Act, Article 15 of the Rules on Physician Surcharge</td>
</tr>
<tr>
<td>Prescription</td>
<td>Article 18 of the Medical Service Act, Article 12 of the Rules on Physician Surcharge</td>
</tr>
<tr>
<td>Handling Record</td>
<td>Article 22 of the Medical Service Act, Article 15 of the Rules on Physician Surcharge</td>
</tr>
<tr>
<td>Opinion on Examination</td>
<td>Article 22 of the Medical Service Act, Article 15 of the Rules on Physician Surcharge</td>
</tr>
<tr>
<td>Radiograph/Opinion</td>
<td>Article 22 of the Medical Service Act, Article 15 of the Rules on Physician Surcharge</td>
</tr>
<tr>
<td>Written Diagnosis</td>
<td>Article 17 of the Medical Service Act, Article 9 of the Rules on Physician Surcharge</td>
</tr>
<tr>
<td>Death Certificate (Written Postmortem Examination)</td>
<td>Article 17 of the Medical Service Act, Article 10 of the Rules on Physician Surcharge</td>
</tr>
<tr>
<td>Birth Certificate</td>
<td>Article 17 of the Medical Service Act, Article 11 of the Rules on Physician Surcharge</td>
</tr>
<tr>
<td>Dead Body/Stillborn Certificate</td>
<td>Article 17 of the Medical Service Act, Article 11 of the Rules on Physician Surcharge</td>
</tr>
<tr>
<td>Report on patients with infectious disease, suspected patients with infectious disease, and possessors of pathogen</td>
<td>Article 11 of the Infectious Disease Control and Prevention Act and Article 6 of its Enforcement Rules, Article 7 of the Rules on Health Diagnosis for Sexually Transmitted Diseases and Acquired Immunodeficiency Syndrome</td>
</tr>
</tbody>
</table>
## Appendix

<table>
<thead>
<tr>
<th>Personal Information File Name</th>
<th>Legal Grounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation of emergency patient</td>
<td>Article 11 of the Emergency Medical Service Act, Article 4 of its Enforcement Rules</td>
</tr>
<tr>
<td>Report on the fact of diagnosis and examination of infectee</td>
<td>Article 5 of the Prevention of Acquired Immunodeficiency Syndrome Act</td>
</tr>
<tr>
<td>Report on the side effects of specific blood transfusion</td>
<td>Article 10 of the Blood Management Act, Article 13 of its Enforcement Rules</td>
</tr>
<tr>
<td>Report on a patient estimated to have had brain death</td>
<td>Article 17 of the Internal Organs, Etc. Transplant Act, Article 11 of its Enforcement Rules</td>
</tr>
<tr>
<td>Briefing, report, notification, etc. of discovery of a patient with disease or a person suspected to have the disease</td>
<td>Article 5 of the Framework Act on Health and Medical Services</td>
</tr>
<tr>
<td>Reading of patient treatment record and issuance of a copy</td>
<td>Article 21 of the Medical Service Act, Article 13-2 of its Enforcement Rules</td>
</tr>
<tr>
<td>Request for medical care benefit</td>
<td>Article 41 of the National Health Insurance Act, Article 2 of the Rules on Standards of Medical Care Benefit of National Health Insurance</td>
</tr>
<tr>
<td>Report on the results of foreign patient attraction business</td>
<td>Article 27-2 of the Medical Service Act, Article 19-9 of its Enforcement Rules</td>
</tr>
<tr>
<td>Category</td>
<td>Details</td>
</tr>
<tr>
<td>Basic Information of Patients</td>
<td>Name, age, date of birth, address, contact information, place of work, family relations, etc.</td>
</tr>
<tr>
<td>National Health Insurance and Welfare Information</td>
<td>National Health Insurance information, record of the disabled</td>
</tr>
<tr>
<td>Information for Treatment Management</td>
<td>Treatment information, applied insurance information, date of visit, hospitalization/discharge, etc.</td>
</tr>
<tr>
<td>Life Background Information</td>
<td>Drinking or not, smoking or not, mental condition, etc.</td>
</tr>
<tr>
<td>Medical background information</td>
<td>Weight at birth, treatment record on pregnancy and labor, record on vaccination</td>
</tr>
<tr>
<td>Treatment Record Information</td>
<td>Diagnosis, treatment plan, medical history, etc.</td>
</tr>
<tr>
<td>Order Execution Record Information</td>
<td>Prescription record, surgery record, treatment record, etc.</td>
</tr>
<tr>
<td>Treatment Information Exchange Information</td>
<td>Written diagnosis, etc.</td>
</tr>
<tr>
<td>Treatment Explanation and Consent Information</td>
<td>A variety of explanation information, various consent information</td>
</tr>
<tr>
<td>Summary Information</td>
<td>Treatment summary, hospitalization summary</td>
</tr>
<tr>
<td>Death Record Information</td>
<td>Death certificate, autopsy record, etc.</td>
</tr>
</tbody>
</table>
Appendix

<table>
<thead>
<tr>
<th>Item</th>
<th>Details</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unique Identification Number</td>
<td>An identification information assigned to distinguish individuals. Resident Registration Number, Passport Number, Driver's License Number, Foreigner Registration Number</td>
<td></td>
</tr>
<tr>
<td>Password</td>
<td>A unique string that subjects of information -- those who handle personal information or the like -- when accessing a personal information processing system, a computer for work, or an information communication network must enter together with an identifier and transfer to the system to identify that they are those with rightful access authority. It is a piece of information that is not disclosed to others. Not only the password of those who handle personal information such as a doctor but also the password of the subjects of information such as a user of a homepage are the subject of one-sided encryption.</td>
<td></td>
</tr>
<tr>
<td>Bio-information</td>
<td>Information on the physical or behavioral features to identify individuals such as fingerprints, face, iris, vein, voice, and handwriting, which is processed or generated from those. Since the information has the unique features of each person, however, only those bio-information to identify individuals fall under the object of encryption.</td>
<td>Medical act-related bio-information such as CT image is excluded from the object of encryption.</td>
</tr>
</tbody>
</table>

["Rights to Patients' Medical Information in the Constitution," No. 3 Vol. 11 Constitution Studies, (2005)]
["Legal & Institutional Contemplation on the Protection of Patients' Treatment Information in the Information Age," No. 2 Vol. 8 Korean Journal of Hospital Management, (2003)]

D. Encryption of Personal Information in Medical Institutions

Personal information handled by medical institutions include patients' personal information, especially a great deal of personal information and sensitive information obtained during the processes of treatment request, treatment, and prescription. Major personal information such as unique identification information, password, and bio-information shall be stored in a personal information processing system via protective measures for safety such as encryption or shall be transmitted via a network. The unique identification information, password, and bio-information are personal information that shall be encrypted.

E. Representative Medical Information Systems

– EMR (Electronic Medical Record): A system for storing all treatment information, diagnosis results, prescription results, medicine prescription data, etc. generated in medical institutions.
– EHR (Electronic Health Records): A system for dealing with and storing all medical information not from a single medical institution but from multiple medical institutions.
– PACS (Picture Archiving Communication System): A system for conveying image information shot by using diagnostic imaging equipment via a network.
– LIS (Laboratory Information System): A system for operating all processes including diagnostic checkup and prescription by the department of laboratory medicine, sample acquisition (blood gathering), sample reception, and input of results after checkup by computerization.
RIS (Radiology Information System): A system that computerizes the overall work of the department of radiology from the reception of examination at the department of radiology, shooting, and generation of a result report.

OCS (Order Communication System): A system for computerizing the general details of diseases with focus on patients and for storing the data by step.

F. International Medical Information Standards

HL7 (Health Level 7): It means an international standardization organization organized in 1987 for enacting standards for ensuring the compatibility of information between different medical-related software or the medical information transmission standard itself as prepared by the standardization organization. HL7 is a standard institution to enact those standards on hospital information systems and access to medical equipment. Currently, it has branches in 29 countries including the Republic of Korea, and it is the de facto standard of ANSI for the electronic exchange of medical information [9]. HL7 means an application of the seventh class as the highest level of ISO/OSI. It aims to transmit data between systems most efficiently and to establish a standard that is able to make the least number of errors during transmission for processing a large volume of distributed medical information.

Those standards currently under development include: health and medical information messaging standards (V2.x, V3); standard on a reference information model (RIM), which is an HL7 data model, and a medical logic module (MLM) for supporting the decision-making process and knowledge (Arden Syntax); and standard on the integration of a clinical document architecture (CDA), which presents an XML-type data architecture model to allow the sharing of clinical information online and individual applications -- which are scattered between heterogeneous types from the user perspective -- and personal information (CCOW). The HL7 messaging standard describes a statement on an abstract message structure, the rules on message coding, and a trigger event, which is an application event that triggers a message. Currently, V2.x ~ V3 have been proposed.

Meanwhile, HL7 CDA Release 2.0 has increased machine and human readability by using medical terminology code standards, etc. such as XML, HL7 RIM, SNOMED, and ICD and expanded the scope of support to web browsers supportable for XML and wireless applications. CDA Release 2.0 has been completed in 2005 and is currently approved for ANSI.

G. Wavelet Transformation Coefficients

Wavelet transforms can compose a model of signal, system, and process with a group of special signals. The special signal is called wavelet. It uses a single small wavelet that locally exists as a pattern and expresses it with a random waveform by conducting its transition or using a scale of expansion or contraction.

The mathematical theory prior to the wavelet transforms theory dates a long way back. Specifically, in 1807, Joseph Fourier came up with the Fourier analysis, which can express a single signal by overlapping it with the sine wave and cosine wave. The wavelet presented in the Appendix of Haar's thesis in 1909 was mentioned as a mathematical task for the first time. The Haar wavelet had a feature of completely perishing outside a limited section. The Haar wavelet was not a continuously differentiable function, so it had limitations in application.
Afterward, the interest of mathematicians shifted from the concept of frequency interpretation to scale interpretation to generate a mathematical structure wherein the scale changes. Such scale interpretation is less sensitive to noise since it measures the average perturbation of a signal in different scales. The scope of application of wavelet is extremely broad, so you can examine the frequency of a specific part of a signal, smooth out a signal including noise, and obtain the boundary between signal and noise. You can also apply it to the interpretation of time series, compression of a signal, interpretation of malfunction of a control system, etc. Wavelet transforms’ practicality was first acknowledged when Morlet, an oil exploration technician from France, actually applied it in 1982. Morlet conducted a joint study with Alex Grossmann, a theoretical physicist, to define wavelet transforms broadly from the perspective of quantum mechanics at that time. Wavelet transforms use a variable wavelet-generating function. A long interval is used for the analysis of low-frequency information, which is just a little higher, whereas a short interval is used for high-frequency information. As the biggest features of the wavelet, the features of the Fourier interpretation express a signal in a frequency area and the possible time-frequency interpretation, which can variably deal with even timely or spatial progress at the same time.

The Fourier transform does not have time information, so it cannot be used for time-frequency interpretation. Thus, you can use the STFT to know the time information by introducing the concept of time window to the Fourier transform. Nonetheless, the biggest problem in the time-frequency interpretation of STFT is that there is no similarity of the base.

The original Fourier transform’s base is similar, so it sensitively reacts to singularity to be used for the detection of a malfunction or the like. In STFT, however, a time window is granted, and the similarity is broken; hence the decreasing sensitivity to singularity. As such, a method was devised to conduct a time-frequency analysis without breaking the similarity of base, and this is called wavelet transforms.

As the features of the time-frequency interpretation by wavelet transforms, the time resolution is high in a high-frequency area, and the frequency resolution is high in a low-frequency area. Therefore, wavelet transforms are more effective in time-frequency interpretation than in STFT. This is because the point of time of change (position) is important for a fast-changing signal, whereas the cycle or frequency of change is important for a slowly changing signal.
Appendix

H. Configuration of the Smart System (Existing)

I. SMARTSOUND’S AWARDS

Mar. 2018. IoT ASIA 2018 Trailblazer Award (first Korean company to receive the award)
Jul. 2016. IoT Innovation Award – Grand Prize
Sep. 2015. App of the Year - Grand Prize (Health/Medicine)
Sep. 2015. Selected as 1st K-Health Member.
May 2015. Selected as one of HIT 500 Products.
Oct. 2013. GD (Good Design) - Grand Prize
Appendix

J. Details of Smart Stethoscope Technology

Latest Precision Auscultation System

- A design of a diaphragm (vibration plate) and a sound-collecting structure, which considers the optimal auscultation function by separating the sound-collecting unit, the transceiver unit, and the processing unit.
- An easy-grip design that considers user convenience.
- Heart sound measuring mode for adults, Heart sound measuring mode for fetus, Lung sound measuring mode
- Sound frequency range of each mode
  - General adult mode: 20-200 Hz
  - Fetus mode: 60-400 Hz
  - Lung sound mode: 60-2,000 Hz, with emphasis on 300 Hz

Sound Collection & Pre-processing Technology, Latest Analysis Algorithm

- Multiple applications of low-pass filters and high-pass filters.
- Removal of noise and reinforcement of sound considering the features of low and middle sound of smartphones.

Heartbeat recognition and regularity algorithm patented by Smartsound

- Precise exploration and matching of S1 and S2.
- Accuracy of 99.99% or higher based on actual determination by human beings on the accuracy of heartbeat.
- Determination of abnormal heartbeat in accordance with regularity.
Exploration of S1 and S2 and matching of heartbeat in a sound source extracted from the Skeeper

Calculation formula for heartbeat regularity (partial)

\[ d_i = t_i - t_{i-1} (i > 0) \]

\[ \text{Avg}(n) = \frac{\sum_{i=1}^{n} d_i}{n} \]

\[ \text{Stddev}(n) = \sqrt{\frac{\sum_{i=1}^{n} (d_i - \text{Avg}(n))^2}{n}} \]