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The Biological Signal Visualization Algorithm for Heart Surgery Simulator

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***Abstract*— This paper introduces a bio-signal visualization algorithm for developing a cardiovascular medical virtual training simulator. It provides opportunities for practitioners and specialists who have complicated medical practice to perform enough training exercises. To reimplement the current study operation situation as much as possible, we implemented an algorithm that can easily identify each biological signal based on the patient monitoring system by visualized. In the future, combining physical engines with valid verification of whether they are suitable for actual medical staff and building simulations. That is identical to actual surgical conditions will enable more scenarios for patient diagnosis and more training programs in various healthcare fields. It produces talented individuals with specialized skills for medical personnel by training in multiple health care fields and more patients' conditions. In addition, for emergencies and emergencies in a real surgical environment, patterns through pulse rate/blood pressure changes were implemented when certain values were entered. Users could be given various situations through the WebSocket communication method as a shield to provide them with specific situations (sudden blood pressure reduction, pulse rate rise, and breathing anxiety) suitable for each training scenario. Also, our method interacts with the user in real-time, keeps the signal uninterrupted and continuous when it gives signals such as a particular situation.**

***Keywords*— Heart surgery; Physionet database; biological signal; virtual extractor; visualization.**

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I. INTRODUCTION

Recent advances in medical technology have increased medical orders, and as the complexity and equality of patients increase, medical staff with professional knowledge and skills are required. Cardiovascular patients are continuously exposed to medical accidents because they need to be skilled and well-informed, highly knowledgeable, highly skilled, highly skilled medical equipment and basic nursing. They need to make quick decisions in the patient's condition in a critical situation [1], [2] because cardiovascular disease techniques rely entirely on the proficiency of the medical staff performing them.[3], [4]. Moreover, there is a very high risk of being exposed to medical accidents if they are not skilled. Due to the devices' nature, even small medical accidents often lead to death, so sufficient training is required. However, compared to this importance, medical activities that can be performed at actual clinical sites are reduced to observational clinical practice. Practice for patients at clinical practice is further restricted, making it difficult for students to have sufficient hands-on experience to perform their role as new medical staff during pre-clinical practice and have and train a practical doctor in a short period. Therefore, an alternative is needed to overcome the limitations of clinical practice and improve clinical performance. It leads to insufficient hands-on opportunities, poor clinical performance, and a lack of confidence in dealing with emergencies due to difficulties adapting to the new environment, even after actual students complete clinical trial training [5]. In many countries, including Korea, medical students and residents practice surgical skills with animal organs and tissues due to medical training that cannot be directly practiced on the human body. Still, in some countries, such practice is sometimes fundamentally impossible, and the domestic also has reduced educational, and training opportunities for animals as regulations are expanded. The number of experiments on animals used in experiments is limited by revising the Animal Protection and Ethical Problems of Experimental Animals Act. There must be experienced doctors to raise doctors in apprenticeship. However, in countries with an absolute shortage of skilled doctors in the first place, it is difficult to expect medical personnel to be released through conventional methods, and despite the importance of medical practice due to the above limitations, medical practice is absolutely lacking. In other words, training is required through a new type of surgical training to create an environment similar to taking care of actual patients in order to train or evaluate medical personnel, such as doctors and nurses. Therefore, in this paper, in order to provide medical education and training opportunities in limited situations, we introduced an algorithm that visualizes biosignals related to the cardiovascular system that can easily reproduce various emergencies. This provides ample training and virtual practice opportunities for professionals who cannot easily have the opportunity to train. In the future, using simulation training developed through visualized algorithms, education, and training program that applies scenario. The situations are similar to the actual clinical situation will be built, and educators will provide real-time feedback through monitoring to effectively train new medical staff and improve educators' education effect. It will be easy to train under various patient conditions through simulators with systematic educational evaluation systems, not training.

II. Material and Method

To improve the level of medical staff required by actual clinical sites, ECGs and other biological signals that can occur depending on the conditions of the virtual surgery environment system were used to organize various emergencies and unexpected events in various surgical situations [6].

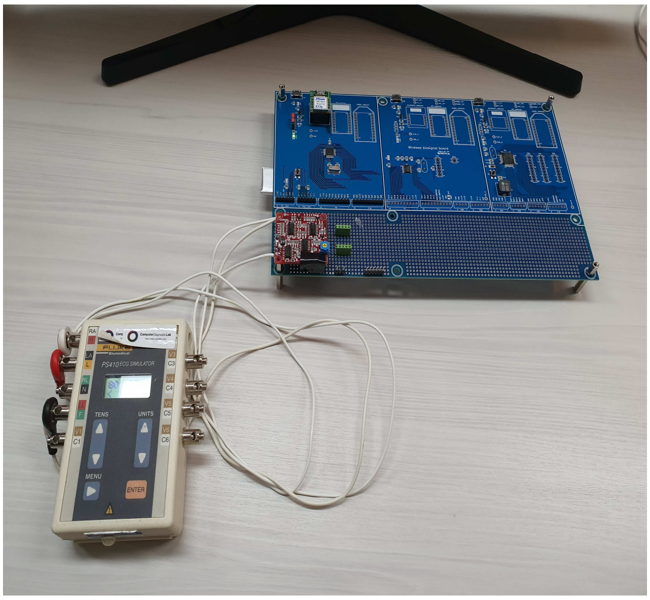


Fig. 1 Collect ecg data using arrhythmia generator and ecg sensor

ECG signals are amplified and filtered by the biometric measurement module and collected in real-time, transmitters, and data. The accuracy of signal measurement was increased by minimizing noise through filtering using transmitted data.

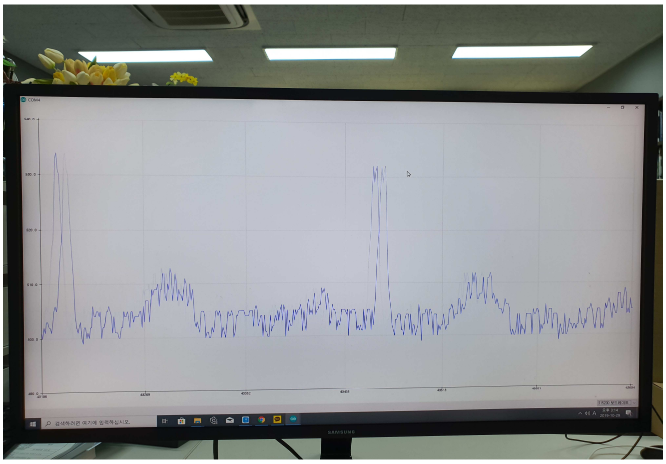


Fig. 2 ECG waveform data

Physionet, highly utilized globally and domestically, was applied to obtain data for each biosignal needed for the simulator. Physionet provides free recorded physiological signals for the study of complex biomedical and physiological signals. There are more than 36,000 records of digitalized physiological signals. As shown in the table below, it has a database of many biological signals from resilience conditions and patients of various conditions, including congestive heart failure, atrial fibrillation, ventricular arrhythmia, acute cardiac death, and various heart diseases.

TABLE I
Heart Disease Database

Database	waveform
Multi-Parameter	ECG, continuous invasive blood pressure, respiration, oxygen saturation, and EEg
ECG Database	most of include ECG signals.
Interbeat (RR) Interval Data	RR intervals data
Other Cardiovascular	contain stride interval (Gait cycle duration)
Neuroelectric and Myoelectric	EEG, EHG, and more.

Patients and diseases in PysioBank provide the values of cardiac disease data were checked. The variables ORSP peak, RR, and PR segment was extracted using biometric analysis by filtering the data. The extracted data were used again as information values of algorithm visualization through data pre-processing.

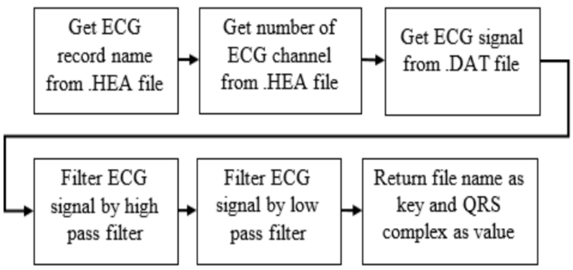


Fig. 3 Data Variable extraction

Variables of ECG waveforms can verify bpm value by lead, depending on the data, extracted and the time-based values of the corresponding biological signals, such as NIBP, SpO2, and Rep verified through the information recorded in each data record.

In order to utilize the data collected earlier as data for use in virtual patient signal simulation, R-R values were calculated by quantifying each data value for each biological signal and detecting R-peak values in the ECG waveform for each situation. The data was organized for the simulated patient data information so that various patient care could be viewed by distinguishing between patient targets (height, weight, age, and gender).

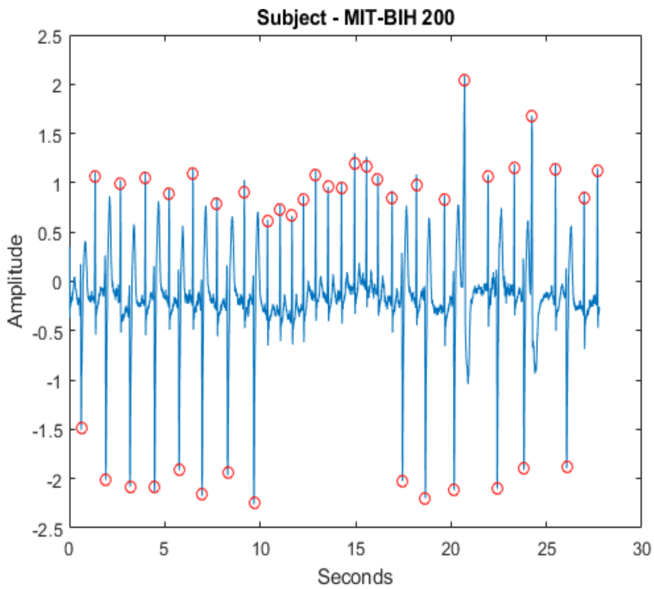


Fig. 4 ECG waveform r-peak value detection

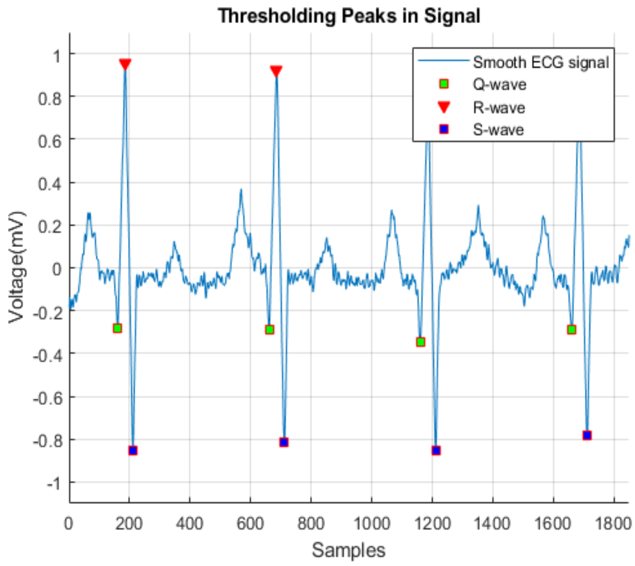
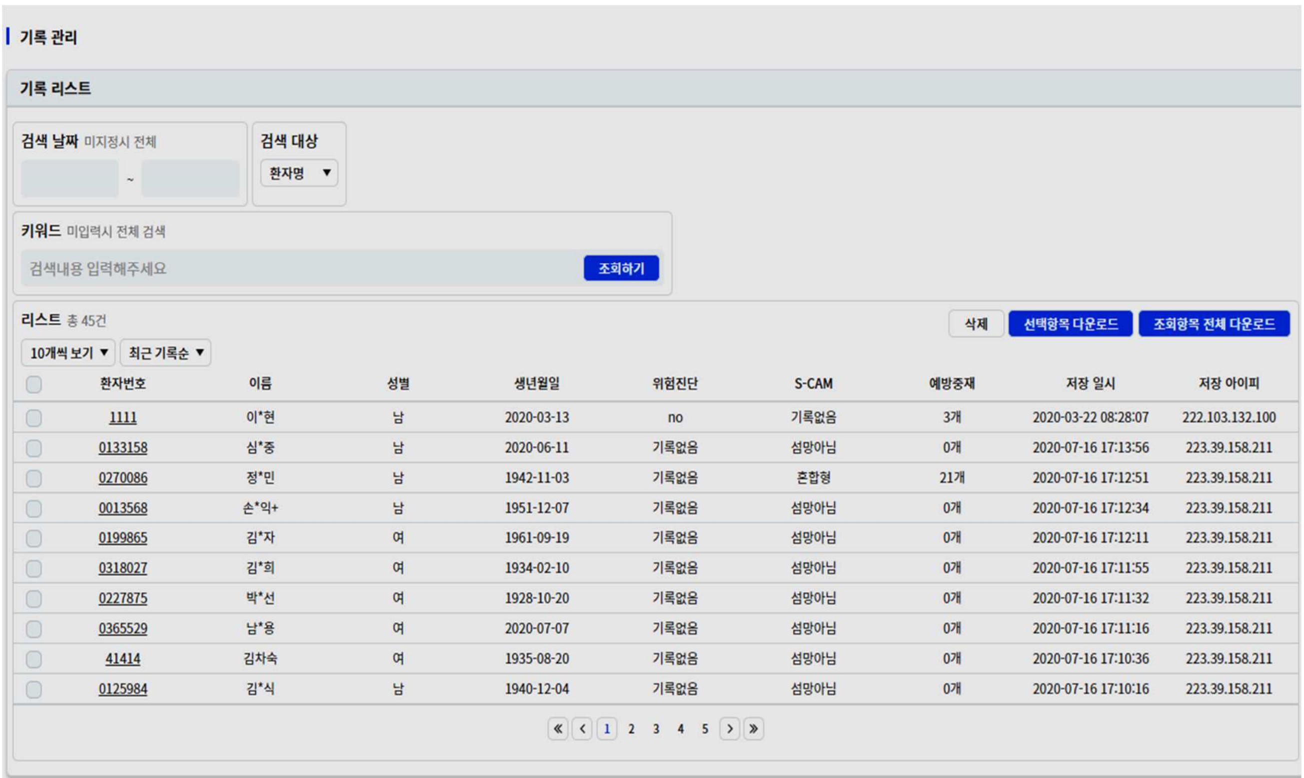


Fig. 5 Verify ECG waveform q,r,s-wave values

The biometric data collected by various diseases such as arrhythmia generators and Pisionets were classified through the server through data quantification. Through the manager window, information on patients currently in the possession and patient characteristics information on what diseases the patient has, and data information values can be checked according to the disease. The types of cardiac disease data currently collected include Atrial fibrillation [32 cases], Constructive Heart Failure Database [23 cases], Arrhythmia Database [34 cases], Superventular Arrhythmia Database [41 cases], and Ventricular Tacharythmia Database [30 cases]. The picture below shows the ECG waveform data collected for the actual patients with cardiovascular disease.



환자번호	이름	성별	생년월일	위험진단	S-CAM	예방중재	저장 일시	저장 아이피
1111	이*현	남	2020-03-13	no	기록없음	3개	2020-03-22 08:28:07	222.103.132.100
0133158	심*중	남	2020-06-11	기록없음	섬망아님	0개	2020-07-16 17:13:56	223.39.158.211
0270086	정*민	남	1942-11-03	기록없음	혼합형	21개	2020-07-16 17:12:51	223.39.158.211
0013568	손*익+	남	1951-12-07	기록없음	섬망아님	0개	2020-07-16 17:12:34	223.39.158.211
0199865	김*자	여	1961-09-19	기록없음	섬망아님	0개	2020-07-16 17:12:11	223.39.158.211
0318027	김*희	여	1934-02-10	기록없음	섬망아님	0개	2020-07-16 17:11:55	223.39.158.211
0227875	박*선	여	1928-10-20	기록없음	섬망아님	0개	2020-07-16 17:11:32	223.39.158.211
0365529	남*용	여	2020-07-07	기록없음	섬망아님	0개	2020-07-16 17:11:16	223.39.158.211
41414	김차숙	여	1935-08-20	기록없음	섬망아님	0개	2020-07-16 17:10:36	223.39.158.211
0125984	김*식	남	1940-12-04	기록없음	섬망아님	0개	2020-07-16 17:10:16	223.39.158.211

Fig. 6 Biometric data base manager page

Fig. 7 Atrial fibrillation data

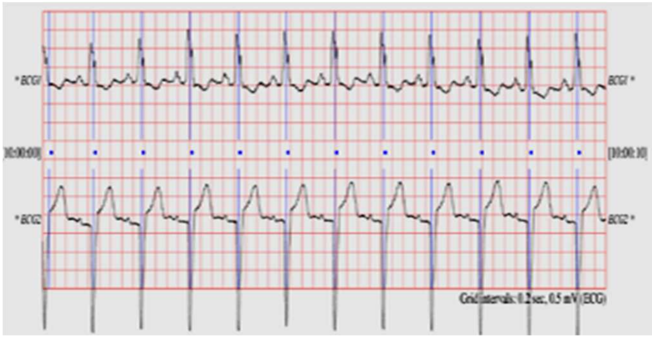


Fig. 8 Constructive heart failure data

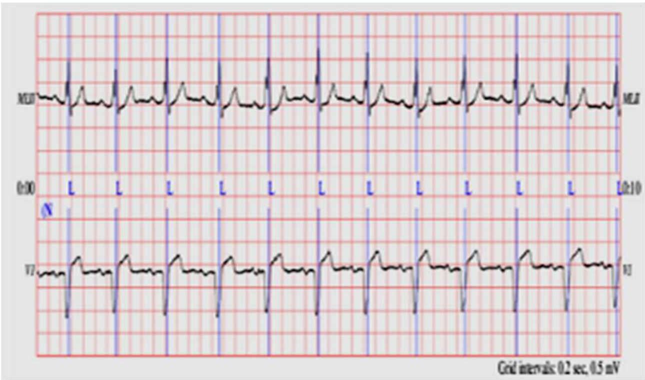


Fig. 9 Arrhythmia data

Fig. 10 Superventular arrhythmia data

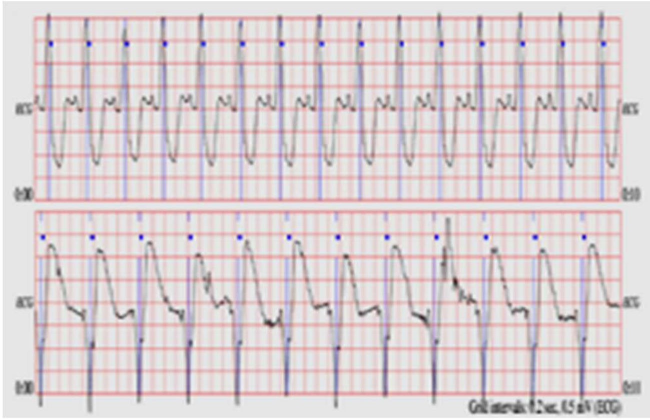


Fig. 11 Ventricular tachyarrhythmia data

III. Results and Discussion

In order to implement a visualized virtual patient monitoring device applicable to the virtual environment through the development of next-generation surgical information visualization technology for advanced medical technology virtual training, the QRSP peak point was calculated from the data value previously converted, and the waveform was displayed according to the cycle of the data value. The RR and PR interval values were calculated to show pulse rate. In addition, data values such as NIBP (non-invasive blood pressure), SPO2 (blood oxygen saturation concentration), and Response (resp) recorded in the records for each data were checked by time, indicating the results of each biological signal value as follows.

ECG (BPM) A record of the heart's electrical activity measures the hearts' rate and consistency. Heart rate is detected as a heart rate indication and displayed through a blink at the same time. The QRS limit is set at the upper and lower heart rate, and the alarm is set to sound when the limit is exceeded. The PACEMAKER signal was detected, displaying the heart rate per minute simultaneously as the detection and flickering.[7]

Fig. 12 Virtual patient monitoring system bpm

Indication of non-blood pressure (NIBP) indicated the interval time when measuring blood pressure periodically by marking the type of measurement cuff and indicating the measurement time and measurement cycle. The systolic blood pressure and relaxer blood pressure values were displayed, indicating the lowest and maximum blood pressure values and the average blood pressure.

Fig. 13 Virtual patient monitoring system non-blood pressure (nibp)

The blood oxygen concentration saturation (SPO2) is about 95 to 100 in the normal range, and the pulse rate is displayed to indicate the SPO2 pulse value. The waveform is expressed in the form of a signal intensity bar, and the blood oxygen concentration is expressed as% SPO2.

Fig. 14 Virtual patient monitoring system blood oxygen concentration saturation (spo2)

End-expiratory carbon dioxide concentration (EtCO2) indicates the carbon dioxide concentration value at exhalation and the respiratory rate per minute as the PR value. In the case of FiCO2, the concentration of carbon dioxide at exhalation is indicated.

Fig. 15 Virtual patient monitoring system respiratory rate (etco2)

The blood pressure (ART), systolic blood pressure, and diastolic blood pressure were measured by calculating the average blood pressure, indicating the highest and lowest blood pressure values.

Fig. 16 Virtual patient monitoring system arterial blood pressure (art)

The blood pressure (CVP) is calculated by calculating the blood pressure measurement unit and average blood pressure with the central vein pressure, and the M indicates the set range level: Mean value.

Fig. 17 Virtual patient monitoring system blood pressure (cvp)

The value of body temperature indicates the value of the temperature unit and degree of money.

Fig. 18 Virtual patient monitoring system body temperature.

Utilizing Python 3.6, wfdb, numpy, django, pip, python-tk, git-related Python modules, available in Windows / Linux / Mac OS. On Windows 10 operating system, Install python 3.6, set environment variables, go to the directory where the operating file (transformed source file) is located, and run python manager.py run server from the command prompt. A user can operate the signal display in the browser, and you can check the waveform for the data by selecting the desired data from a biometric database for different diseases and situations. In extracted data source files, a screen-based on patient-sensitive monitors are constructed using a browser or server through HTML, JAVASCRIPT, and CSS, as shown in the picture below [8].

Fig. 19 A virtual patient monitoring system

In addition, for emergencies and emergencies that can occur in a real surgical environment, patterns through pulse rate/blood pressure changes were implemented when certain values were entered. Thus, users could be given various situations through the WebSocket communication method as a shield to give them specific situations (sudden blood pressure reduction, pulse rate rise, and breathing anxiety) suitable for each training scenario [9], [10]

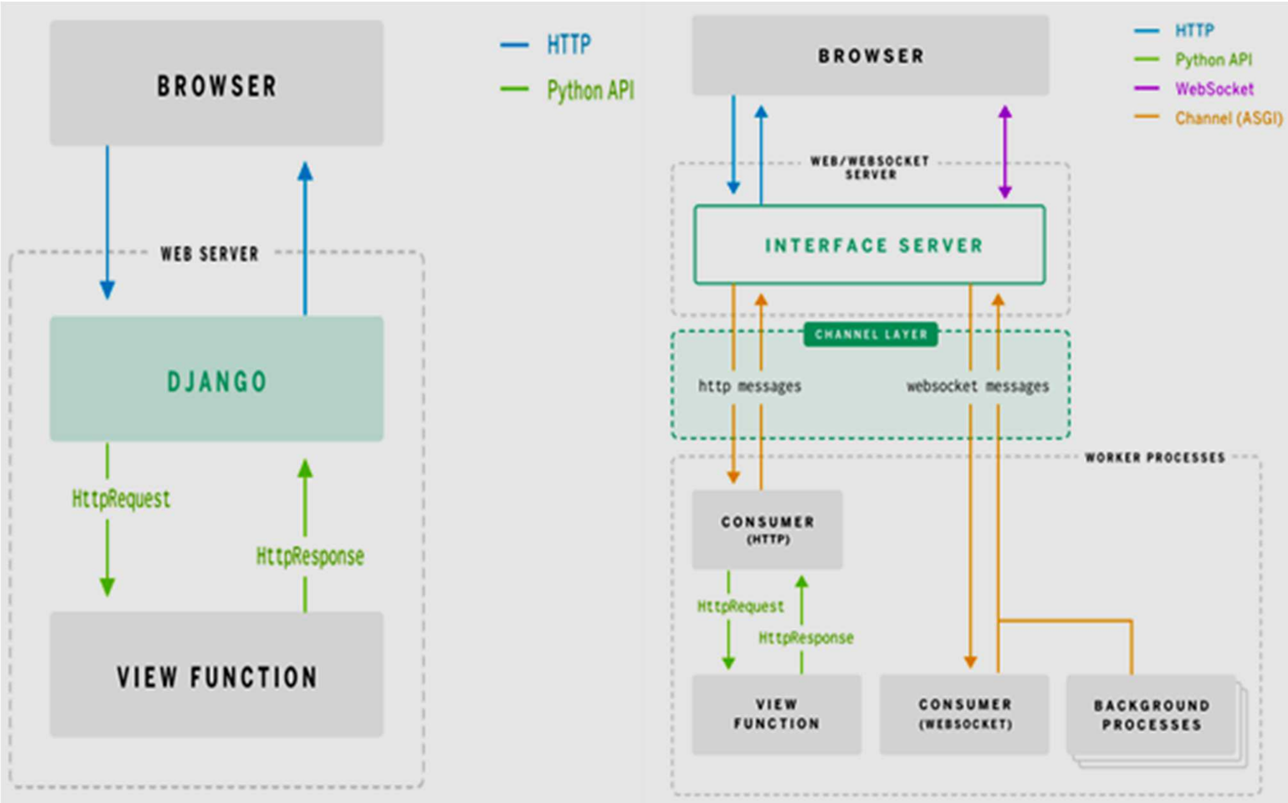


Fig. 20 Existing communication methods (left) and methods using websocket (right)

Existing web browsers have used a full-duplex WebSocket method that uses asynchronous mode for two-way communication to solve this problem, which is impossible to maintain real-time connections like TCP/IP sockets in the request/response protocol [11]–[14]. The free two-way transmission, which interacts with the user in real-time, keeps the signal uninterrupted and continuous when it gives signals such as a particular situation (emergency situation during surgery) [15], [16]. Memory DB (Remote Dictionary Server) that maintains existing signals was used as a memory-based data store, which explicitly sets the deletion and does not delete the data unless it expires [17]–[20].

Fig. 21 Websocket deploying browser version

IV. Conclusion

In this paper, when medical staff with professional instructions and skills are required, especially in the case of cardiovascular care, small medical accidents often lead to death due to their nature. They are poor in practice. They are based on simple empirical knowledge, so that medical staff and patients can gain more systematic and practical experience without being restricted under any circumstances to solve the vicious cycle of repeated medical activities. To reimplement the current operation situation as much as possible, we implemented an algorithm that can easily identify each biological signal based on the patient monitoring system by visualizing it. In the future, it is recommended to combine physical engines with valid verification of whether they are suitable for actual medical staff. Also, it is recommended to build simulations that are identical to actual surgical conditions to enable more scenarios for patient diagnosis. It is also expected to conduct more training programs in various fields of health care. Thus, the upcoming research can produce talented individuals with specialized skills for medical personnel by training in various fields of health care and under the conditions of more patients through their simulators.

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