The Internet of Things system combined with the cloud platform applied to the data collection and analysis of the elderly's home life style

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Abstract—**This study combines Google Cloud Platform (GCP), Google Assistant, Firebase and MongoDB for data streaming and storage through smart bracelets, smart amulets (9-axis IMU), and smart speakers (Google Home Next Mini), and the collected data changes are displayed on the webpage immediately to form a home care internet of things system for the elderly. The experiment visited five groups of families for actual testing, with ten people experimenting for one week, all wearing the smart bracelet and the smart amulet at the same time. The bracelets and amulets were transmitted by Bluetooth broadcasting, and received various physiological information and posture changes through the peripheral devices, which were stored in Firestore (Firebase's no-SQL) and MongoDB and analyzed by Cloud Function to provide relevant recommendations based on the elderly's body information. Finally, the results of the analysis and recommendations are broadcasted by smart speakers to improve the bad habits of daily life. Lightweight and inexpensive wearable devices will reduce the discomfort caused by wearing many sensors in the past, and at the same time will reduce the cost of setting up a home care Internet of Things system, which will assist the elderly in the field of home care by creating a long-term automated care system, giving a major boost to the issue of elderly care in an aging society.**

Keywords-IoT; Smart Healthcare; Data flow; Big Data Analysis; Cloud Services;

I. INTRODUCTION

Many care systems collect various physiological information and activity status of the user through many wireless technologies and sensors [1] and receive this information through peripheral devices or mobile applications so that the user can confirm the current physiological status [2] [3], thus forming a simple care system. In addition, there are also many studies that use a large number of sensors to collect large amounts of data for machine learning analysis of sleep and behavior of the elderly, aiming to confirm detailed sleep status and rhythm of the elderly [4], etc. Sampling of frailty gait and fall patterns, or deep learning or visual analysis training through open-source datasets provided by medical institutions [5], predicts or confirms the occurrence of diseases.

Although the aforementioned studies have employed a wealth of research methods and techniques to perform different aspects of analysis, they have unfortunately not been successfully applied to real-world situations. The extensive use of sensors causes user reactions and inconvenience, as well as tension; it does not maximize the value of the quantified data and causes a decrease in willingness to use. These problems make the system less intelligent and personalized.

Therefore, this study only requires the wearing of the smart bracelet and the smart amulet to improve the discomfort and rebound caused by excessive wearing of sensors in the past. The physiological data from the smart bracelet analyzed the daily physiological status of the subject, and the data from the smart amulet analyzed the walking stability. Several studies in the past found that the duration of TUG was closely related to moderate and severe Parkinson's disease [6]. The duration of TUG can be used to determine whether there is a risk of falling. Finally, the analyzed results were communicated to the subjects through the smart speaker (Google Home Nest mini) as an information disseminator and appropriate suggestions were given.

In Section 2, the experimental system architecture is introduced, using Raspberry Pi combined with smart bracelets and smart amulets with cloud platform services to form an Internet of Things, collecting subjects' physiological data, activity posture and movement status in a lightweight way to establish a daily physiological model. In Section 3, the actual wearing of the smart bracelet and the smart amulet will be carried out for daily physiological status and posture monitoring experiment, and the data will be collected and the subjects will be judged by the "Timed Up and Go Test (TUG) evaluation standard" to determine whether they have weakness symptoms. In Section 4, the data collected from the smart bracelet and the smart amulet are analyzed and the conclusions of this paper and the future directions of optimization are summarized.

II. SYSTEM ARCHITECTURE

The Bluetooth devices used in this study are shown in Table 1. A complete care system is constructed by lightweight and inexpensive devices. The smart bracelet and smart amulet are the only devices that need to be worn. The rest of the devices are fixed and placed to solve the problem of wearing too many sensors while ensuring high accuracy of data.

The smart bracelet can detect the subject's heart rate, blood pressure, body temperature, step count, walking mileage, calories and other daily physiological data; the smart amulet can collect the subject's posture, movement changes, indoor positioning and other data. Since the development of smart bracelets in the market has been quite complete and the types of physiological data measured are quite comprehensive, considering the generality of the future experimental process, we designed the smart amulet to receive data from the broadcast package of commercially available smart bracelets. At the same time, because the smart bracelet function is well developed, we choose not to include the smart bracelet function when developing the smart amulet.

TABLE I. DEVICES USED IN IOT CARE SYSTEMS

Device	Function	Advantage
Smart Bracelet	Blood pressure, Step, Mileage, Temperature, Heart rate and Calorie	with bracelet protocol, Cheap
Smart Amulet (9-axis IMU)	Attitude, Motion, Height monitoring, Fall monitoring, Emergency alert and indoor positioning	With 9-axis sensor, accurate identification
Smart Speaker (Google Home Nest Mini)	Notifications, Conversations, Sentence Collection and Care	Google has a series of services and functions
Beacon	Indoor positioning	Accurate positioning function
Edge Device (Raspberry Pi 4B)	Collect Bluetooth device data and store in database	Speed up data processing and response time

This study is a combination of cloud platform and Internet of Things application, as shown in Figure 1. The data is received from the smart amulet, merged and sent to the edge device, and the edge device sends the data to the cloud database (firestore) of Google cloud platform (GCP) for storage via MQTT, and stored in the local database (MongoDB). The data stored in firestore is classified, organized and analyzed by the cloud function provided by GCP, and the data analysis results are displayed on the web page in real time so that the subjects can view the current physiological data; the data in the local database is used as a data set for future training of the machine learning classifier to maximize the value of the data. The analyzed results are actively pushed through the smart speaker using the data stream integration function of the cloud platform.

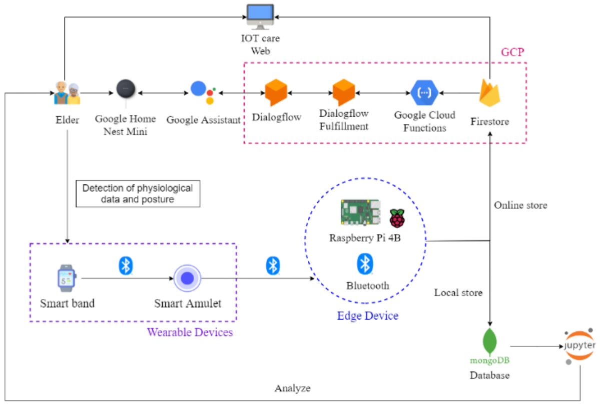

Figure 1. IoT System Architecture Diagram.

In order to realize the function of active push message by speaker, this study uses the triggering function of Cloud Functions and Cloud Pub/Sub to realize it, the data change triggers Cloud Functions through HTTP, Cloud Pub/Sub sends the object to the corresponding topic, the program in Raspberry Pi will subscribe to the same topic, through Google Text to Speech API receives and processes the text content in the object, converts the text content into voice messages, and finally pushes the voice messages actively through Google Speaker, as shown in Figure 2.

When the smart amulet detects that the subject is in an emergency situation, it allows the speaker to make an emergency broadcast through the data stream. Since the smart speaker is placed in the subject's home, the microphone radio system will only be turned on when the smart speaker hears the wake-up call, taking into account the subject's privacy concerns. In the absence of a wake-up call, the subject's privacy is protected.

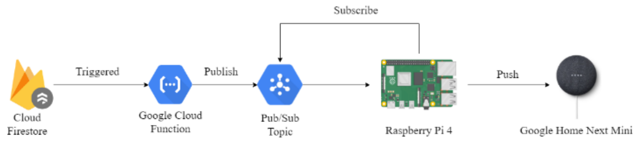

Figure 2. Flowchart of active broadcasting by speakers

III. METHOD

In this section, we describe in detail the types of subjects and the methods used to collect three types of data: physiological data, daily posture and exercise behavior.

A. Subjects

The subjects were 10 people, 5 elderly people aged 70 to 80 years and 5 young people aged 24 to 26 years, and the system was set up in 5 households. The height and weight of the elderly were as shown in Table 2, and the height values shown in Table 2 were measured without hunchback. The purpose of including young subjects in this experiment is to collect comparative data for future training of the frailty classifier. All data were transferred to the cloud and local databases through the edge device. The experiments were conducted with the consent of the subjects who received daily data collection for this experiment.

TABLE II. SUBJECT'S PHYSICAL INFORMATION

Subjects (Elder)	Height (cm)	Weight (kg)	Humpbacked	Illness & Injury
Elder 1	158	62	No	Had ankle surgery
Elder 2	155	58	Yes	Bipolar disorder & Effusion of knee joint
Elder 3	155	45	Yes	Had knee surgery

Subjects (Elder)	**Height (cm)**	**Weight (kg)**	**Humpbacked**	**Illness & Injury**
Elder 4	157	58	Yes	Back sprain
Elder 5	168	65	No	None

B. *Physiological State Data and Daily Posture Collection*

During the experiment, the subjects will be asked to wear the smart bracelet and the smart amulet for 7 days. Except for washing, they would wear them during the rest of the time. The smart bracelet is shown in Figure 3. The smart amulet was attached to the chest by means of biocompatible adhesive, as shown in Figure 4. The purpose of using the adhesive is to control the correctness of data collection, to ensure that the movement of the amulet is consistent with the body movement and does not affect the data interpretation of the 9-axis sensor. If the amulet is worn by hanging, it will cause the smart amulet to shake, which will generate noise and affect the sensor's interpretation.

The 9-axis sensor in the smart amulet includes 3-axis accelerometer, 3-axis gyroscope and 3-axis magnetometer. The coordinate system is shown in Figure 5, which can measure the acceleration, rotation angle and geomagnetic direction respectively, and calculate the subject's posture and movement distance. The G-value (1) can be calculated by taking the root of the sum of the squared acceleration of each axis. The change of G-value is used to determine whether the subject is active or not. If the subject is at rest, the G value is equal to the gravitational acceleration (about 1G).

$$\text{G-value} = \sqrt{(\text{ACC}_x)^2 + (\text{ACC}_y)^2 + (\text{ACC}_z)^2} \tag{1}$$

Through the orientation algorithm (gradient descent algorithm) proposed by Madgwick [7], the acceleration value, magnetometer value, and gyroscope value are calculated to derive the 3-axis rotation angle, which are Roll, Yaw, and Pitch. Observation of Roll, Yaw, and Pitch can analyze the walking deflection condition of the subject.

Figure 3. Smart bracelet to wear on the wrist.

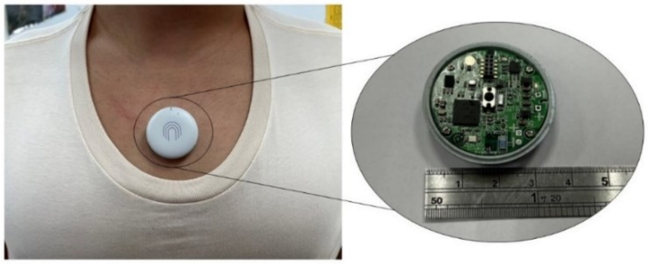

Figure 4. Smart amulet (9-axis IMU) developed and designed by our laboratory

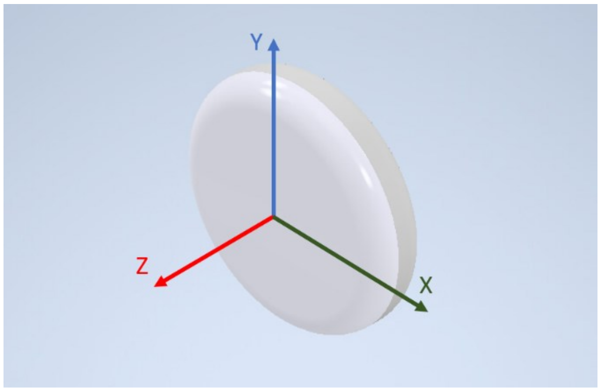

Figure 5. Smart amulet (9-axis IMU) Coordinate System

C. *Behavioral Data Collection*

The Timed Up and Go Test (TUG) frailty assessment standard was conducted to check the movement changes of the subject and to determine whether the subject had frailty symptoms. Time Up and Go Test uses the standard TUG protocol and starts from the center of the foot and goes forward 3m, using tape at the 3m mark and turning around the cross mark. The TUG experiment was conducted using a chair with no back rest. During the experiment, the subjects will wear smart amulets and smart bracelets to collect physiological state data and experimental posture data. Finally, the test results and exercise performance data of young and old people are compared to analyze the differences and train the classifier model.

IV. RESULTS AND DISCUSSION

Based on the system architecture and the experimental method, the experiments are conducted to validate the care IoT cloud system designed in this study, and finally the collected data are analyzed completely.

A. *Physiological Information and Daily Posture Collection Results*

The data collected during the experiment will be uploaded and stored to the cloud database through the edge device, and the current posture changes will be displayed through the webpage for the subjects to view in real time, as shown in Figure. 6. In the future, the system will be developed in such a way that caregivers can check the activity of the elderly in real time through the webpage. For the elderly with frail symptoms, the caregiver can check whether there is a fall in real time. If unfortunately a fall occurs, the fall posture of the smart amulet will be sent to the cloud platform to trigger the speaker to broadcast a fall warning message, and through the screen warning and broadcast warning to achieve double reminders to avoid the regret caused by negligence.

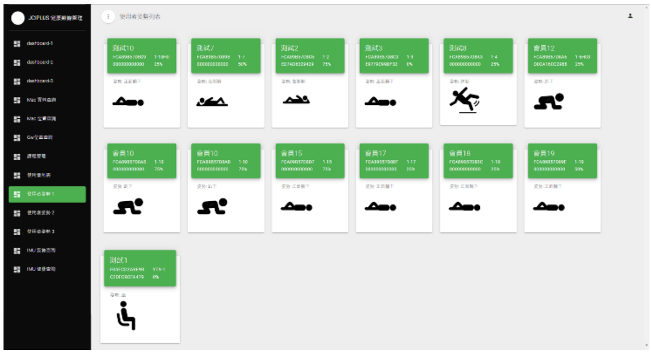

Figure 6. The status of smart amulet is displayed instantly on the web

The physiological data and postural changes collected daily were plotted for analysis. The graphs were used to clearly analyze the physiological data and postural distribution of the subjects during one hour at a point in time, as shown in Figure. 7 and 8. Figure. 7C shows that the blood pressure changes during the first 30 minutes implied a trend of pre-hypertension. According to the criteria for hypertension published by the American Heart Association [8], a diastolic blood pressure between 120 mmHg and 129 mmHg and a systolic blood pressure below 80 mmHg are the criteria for prehypertension. However, the blood pressure status returned to normal in the last 30 minutes, and the heart rate was higher in the first 30 minutes when compared with the heart rate variation graph in Figure. 7A. At the same time, the posture distribution in Figure. 8 showed a prolonged sedentary state, which was verified with the experimental activity records, and the subject was watching a movie at that time, which was presumed to be caused by the tension of the drama.

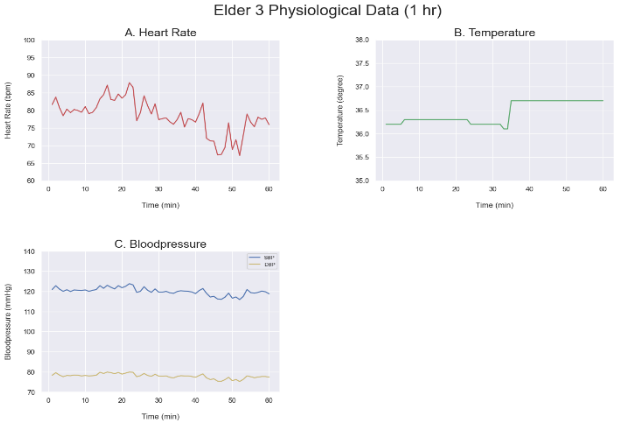

Figure 7. Line graph of the physiological data changes during a certain hour of the experiment (the same sampling time as in Figure. 8).

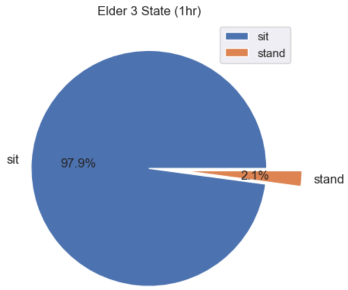

Figure 8. The pie chart of the posture distribution during an certain hour of the experiment (the same sampling time as Figure. 7).

B. Daily Behavior Analysis

The results of the TUG experiment with the same conditions for young person 1 and elder 1 are shown in Figure. 9. The 3-axis acceleration and G-value are magnified 512 times for easy observation and plotting on the graph. From Figure. 9A and 9C for comparison of the difference in 3-axis acceleration changes, we can observe that the amplitude of G-value of young person 1 is larger than that of elder 1. By comparing the amplitudes and observing the experimental procedure, it was inferred that the young people walked at a larger pace and faster speed.

On the other hand, comparing the difference of Z-axis acceleration, the maximum amplitude of Z-axis acceleration reached -400 as shown in the red circles in Figure. 9A and 9C, indicating that elder 1 was leaning forward than young person 1 in getting up, which could be inferred from observing the experimental procedure that elder 1's leg muscles were relatively weak and needed to be guided to stand by body strength. At the same time, the TUG test time of elder 1 was greater than 12 seconds, and it is presumed that there may be a risk of falling [9].

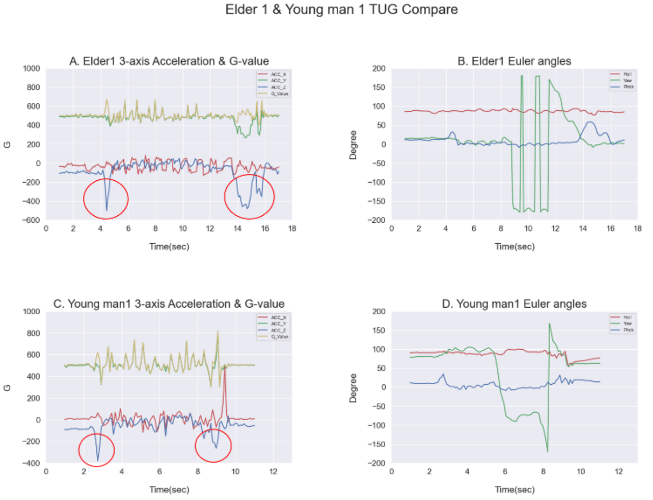

Figure 9. Comparison chart of TUG experimental data between the elderly and young people.

V. CONCLUSION AND FUTURE WORK

Through the combination of physiological data and behavioral posture analysis, the care system can monitor the living condition of the elderly at home more effectively. The smart bracelet and the smart amulet are combined with the edge device to form an Internet of Things for data collection and pre-processing. The edge device uploads data to the cloud platform database and the local database for storage, and the cloud platform further analyzes the data and broadcasts the results through the smart speaker; the local database stores the data for long-term use as a training data set for the classifier model in the future. The system can effectively observe the fall risk of the elderly. The data stored in the cloud database can be displayed on the web page in real time, and the fall can be broadcasted through the smart speaker in real time to avoid regrets. The experimental results confirm that the system designed in this experiment is a cost-effective tool for daily care of the elderly by combining the Internet of Things with the cloud platform. Although this study has completed the design of the elderly care IoT system and conducted some experiments and studies, the hidden risks and varying degrees of cooperation in inviting elderly people to participate in the experiments have led to relatively limited experiments and data collection, and limited sampling target groups. In the future, we plan to enter more homes to conduct experiments and optimize the system function to conduct more realistic and long-term experiments as the primary improvement point. It is believed that a more comprehensive and perfect personalized care system will be established in the near future.

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