Implementation of IoT, Wearable Devices, Google Assistant and Google Cloud Platform for Elderly Home Care System

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Abstract: The purpose of this research is dedicated to designing the care system. By using Google assistant speaker, various sensors, web page, and cloud data processing to design an Internet of Things environment combining health information and various parameters to improve the quality of the care system. We use wearable devices to transmit physiological information, then collect data through Bluetooth sensors and upload them to the database via edge devices. At the same time, it monitors unusual values at any time. Then, it notifies users through google assistant to trigger Google Home System. We carry out cloud data analysis and optimize dialogue patterns by obtaining physiological information, escorting services, recording conversations, and other forms of active questioning. Through using conversation feedbacks as data, we can also generate simple data analysis, fill out various questionnaires by using the web pages. With this complete care system, the cloud data is integrated and networked to provide a better care system for the elderly.

1 INTRODUCTION

The Internet of Things means that there is a large number of composite data through statistics and analysis, which can get relevant information that was previously ignored by a single data. Conducting to solving problems in various fields such as smart home care, this research focuses on providing services between smart homes and elderly care, by using the data collected from the sensor and Google Home System to perform a series of verification, processing, classification, storage, statistics, and visualization on the data for the user or their caregiver. Those data can help them to make plans for improving their health.

The main purpose of the Internet of Things application is to provide humanized services, making family life more comfortable, safe and energy-efficient, and processing some of the more burdensome computing by the cloud, which can quickly adapt to changing loads. Therefore, the integration of smart homes into the cloud and obtaining more information from the cloud will help provide more humanized services. This is the goal of smart homes for IoT applications now (Haijun Gu, Yufeng Diao, Wei Liu, and Xueqian Zhang, 2011). The services provided by the smart home can be roughly divided into many types (Xiaojing Ye and Junwei Huang, 2011). (1) Environment: air-conditioning, water, lighting. (2) Safety: fall, injury, and break in. (3) Entertainment: TV, stereo. (4) Electrical appliances: Recipe suggestions, automatic cooking, cleaning, refrigerator inventory. (5) Message and communication: alarm, home calendar, remote control. (6) Health: behavior, medication, sleep, etc. In response to demand, well-known companies such as Google, Amazon, Microsoft, IBM, etc. have all proposed SaaS (Software as a Service), PaaS (Platform as a Service), and IaaS (Infrastructure as a Service). This research is to develop PaaS among them, establish a service-oriented cloud computing architecture and provide users with SaaS. Users can use our existing services through simple settings. In reference (M. M. E. Mahmoud et al., 2018), there is a new term named COT (Cloud of Things), after integrating the cloud and IoT, all IoT devices can be accessed through the cloud as a service, the role of the cloud in COT is a middleware between things, this

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research on health services is still focused on individual sensor values. As the result, it cannot clearly understand the impact of external factors on users.

In this study, with Bluetooth devices as the main body, we integrate indoor positioning services, and various interactive devices as the collocation mesh network of Bluetooth nodes which are used to upload data to the cloud. In order to help elderly easier to use the system, we use Google Home Nest Mini to notify abnormal physiological signal from the wearable devices and design dialog system to give them advices about health. At the same time, we record these conversations to help doctors or their caregivers. On the other hand, doctor or their caregiver can monitor, remotely control and obtain statistical behavior information by web in real time. Unlike reference (D. C. Yacchirema et al., 2018), with a long-term behavioral record, it is possible to understand what bad habits may cause problems before getting sick and be proactively alerted. Medical information and long-term behavioral records help us to find out what the real causes are.

2 IOT SYSTEM ARCHITECTURE

2.1 System Architecture Level

The system combined light source devices and Bluetooth devices. It uses wearable devices and fixed sensors for positioning tracking, activity monitoring, behavioral mode judgment, and fall notifications. By building a network with each other through Bluetooth wireless communication technology, sensors can automatically sense and count data. The Bluetooth mesh network pushes the data to the terminal and uploads data to the cloud by Wi-Fi and stores data in the cloud database. This system has 3 ways to notify or show data for users, web interface, asking for information from Google Nest Mini or notifying messages by using Raspberry Pi.

The IoT system architecture is mainly divided into six levels. The architecture diagram is abstractly presented in “Figure 1”.

2.2 Wearables and Fixed Devices

The sensors of this system are wearable devices, fixed devices, and Google Home Nest Mini.

Wearable devices are Bluetooth watch and Bluetooth tag, as shown in “Figure 2”. Bluetooth watch uploads physiological data, like heart beat rate per minute. The Bluetooth tag is designed to detect the user's movement and their location.

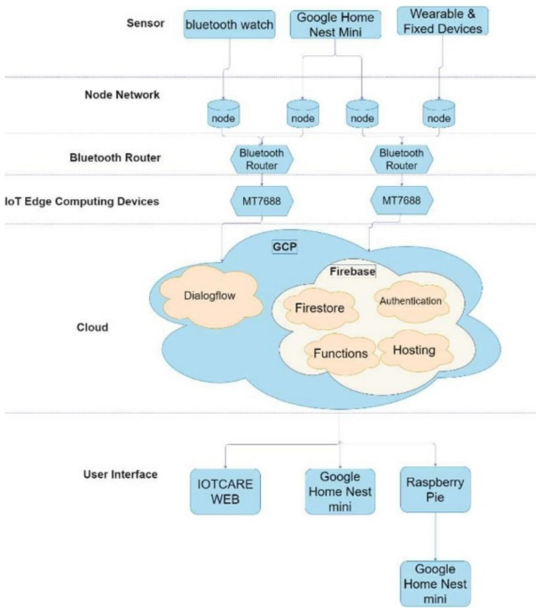

Figure 1: System architecture hierarchy diagram.

Fixed sensor means contact sensors and Google Home Nest Mini. They both are triggered by a person. The difference is the way how to trigger them. As shown in “Figure 3”, such as magnetic reed switch, seat cushions and pedal mats, they are triggered by physical contact. And Google Home Nest Mini is triggered by audio messages from user.

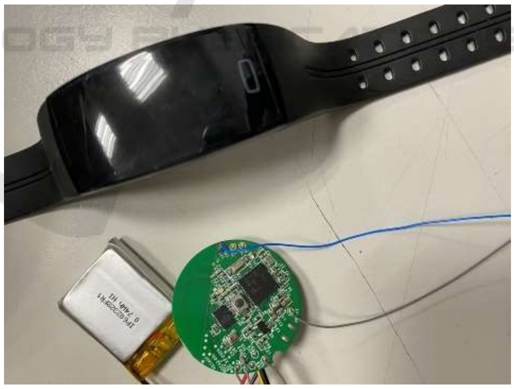
Figure 2: Bluetooth watch and Bluetooth tag.


Figure 3: Contact sensor, cushion (left), step cushion (right).

Google Home Nest Mini is running based on GCP services that help us to create dialog system to process audio messages. In the processing, it can classify different dialog intents, events, responses and records. On the other hand, the design of the smart seat cushions and pedal mats uses silicone rubber as the dielectric material. Through the calibration algorithm, the capacitance value is converted into the corresponding pressure for comparison and analysis to determine the sitting posture, for example, normal sitting, forward, left, right. By recording the position of the center of gravity of the posture and analyze its proportion, it may correct the elderly's sitting posture to avoid scoliosis and elderly falling.

2.3 IOT Edge Computing Device

An edge computing device is located on the edge between two networks. Edge computing is the decomposition of large services that were completely processed by the data center through cutting the service into smaller and more manageable parts, scattered to the edge nodes for calculation (W. Shi et al., 2016). Edge computing can speed up data processing and transmission speed, reduce network latency. Under such a structure, the analysis of data will be closer to the source of the data, so it is more suitable for processing a large amount data collected by sensors.

2.4 Bluetooth Mesh

The Bluetooth mesh network is constructed by many bNodes and a bwRouter. The Node device is equipped with two Bluetooth roles central (Master) and peripheral (Slave). The former will scan the broadcast channel at 20 ms intervals, and only receive our proprietary protocol. Master is transmitted the data of the communication protocol to the slave station through the UART communication interface. The latter is in addition to provide broadcast location packets for wearable device positioning, the data sent by the host will be considered as priority forwarding data. The data will be continued to send to the next bNode until the master scans its own return packet and notifies the slave device to stop broadcasting. This design not only ensures that each piece of data reaches the next bNode, but also reduces end-to-end latency. Based on this design, it can build a Bluetooth mesh network. “Figure 4” is describe the bNode workflow among multiple bNodes.

The bwRouter consists of Bluetooth and Raspberry Pi. It inherits the bNode function, and also it is the top layer of the Bluetooth mesh network. It acts as a communication bridge between BLE and

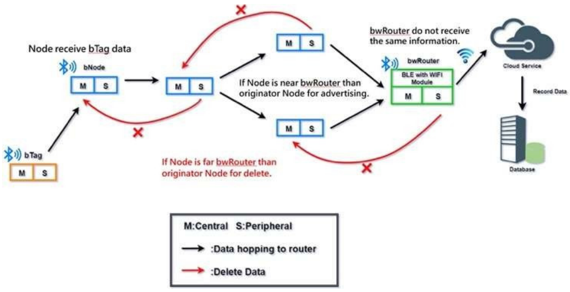

Figure 4: bNode upload and transfer process Diagram.

WIFI. BLE uses the UART communication interface to send data to the Raspberry Pi, and then uploaded to the cloud via WIFI for data storage and analysis. The bwRouter can send acknowledgement to the bNode or send commands to the lower-layer devices of the BLE mesh network to implement a two-way transmission system.

2.5 BLE Initial Setting

Mobile phone application plays a role of setting terminal as shows in “Figure 5”. The system uses Android and IOS phones as the main mobile devices. Bluetooth mesh networks use a method called "Flooding" to publish and relay messages. In order to let Flooding have direction, the mobile phone establishes a connection between the bNode, bwRouter and the fixed devices and write the information. This information is obtained from the Google Map in mobile phone application where gives the absolute position to itself and let each bNode know the location of the bwRouter, and then writes the mesh group to each bNode. This method provides bNode master judging bwRouter distance and makes the data transmission directional. In addition to setting the latitude and longitude, it can also divide the area, such as restaurant, bathroom, living room, balcony and kitchen.

Figure 5: IOS APP setting interface.

3 CLOUD SYSTEM ARCHITECTURE

This research uses some of the cloud capabilities of Google Cloud Platform such as Web development framework, related development tools and Google Home Nest Mini. In order to store personnel indoor positioning and behavior data collected by sensors into the NoSQL database for web and APP request, batch output historical data, output statistical reports through data ETL (Extract-Transform-Load), analyze of elderly behavior, and push messages through social media and smart speakers (Google Home Nest Mini). It can analyze elderly behavior, and push messages through social media and smart speakers (Google Home Nest Mini). There will be detailed introduction and description below. The cloud architecture diagram of this system is shown in “Figure 6”.

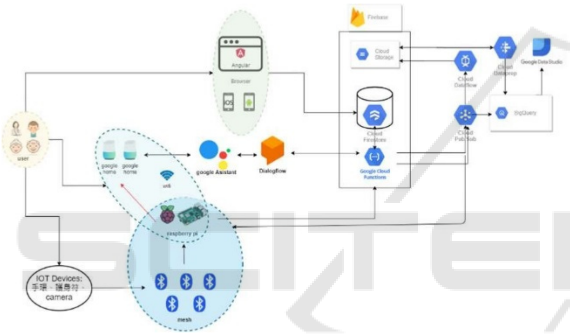

Figure 6: Cloud system architecture diagram.

In this system, we use Google Home Nest Mini in many ways, such as notify user, company with user by messages and record messages about geriatric depression scale (Keelung City Government,2017) to take care of their health. The dialog flow is shown in “Figure 7”.

At the beginning, users use their voice to awake Google Home Nest Mini and it will response “How are you?”. If users keep talking with Google Home Nest Mini, it will take those messages to trigger Firebase Function that Firebase Function will save messages to Firebase and push messages to Google Home Nest Mini. In “Figure 7”, we take problems in Geriatric Depression Scale (Keelung City Government, 2017) for example. When user tell it their “feeling”, it will trigger Firebase Functions to collect the questions by “feeling” and respond a random question in the questions. Then users answer the question, Firebase functions will save messages, score each answers and push messages back to comfort users.

In order to collect the messages, we coded lots of functions and designed different conversation templates to create each dialog flow in Google Home Nest mini.

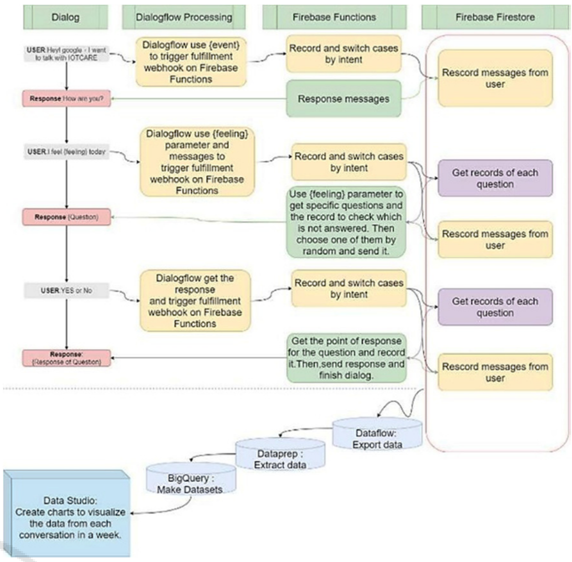

Figure 7: Dialog process in Google Home.

3.1 Angular Framework

It is one of the UI service webpages in the system. In order to efficiently make the data collected by a large number of IOT sensors responded to users in real time, this research uses Angular to build a client application platform. Dialogflow

3.2 Dialogflow

Dialogflow is a natural language understanding platform that makes it easy to design and integrate a conversational user interface into mobile app, web application, device, bot, interactive voice response system, and so on. Using Dialogflow, we can provide new and engaging ways for users to interact with Google Home Nest Mini.

Dialogflow can analyze multiple types of input from user, including text or audio inputs (like from a phone or voice recording). As the result, we can use it to design dialog and set fulfiilment webhook with Firebase Functions that we can program those parameters, give response to Google Home Nest Mini and upload data to Firebase Firestore.

3.3 Actions on Google

Actions on Google is the developer platform for creating conversational apps for the Google Assistant and publishing them to Google Home, Android, the

Google Assistant app on iPhone, and beyond.

It is used to deploy our application on Google Home Nest mini and manage with different GCP services.

3.4 Google Home App

The Google Home app helps us to set up and control Google Nest, Google Home, and Chromecast devices. We can control thousands of compatible lights, cameras, speakers and more, all from a single app, as well as check reminders and recent notifications.

Google Home app also help us to get wifi mac address to set up Raspberry Pi, distinguish different devices and use voice-match with g-mail to login user.

3.5 Cloud Functions for Firebase

Because the user interface of this system includes web pages, Android IOS APP and Google Home Nest Mini. User often adds, deletes, modifies, and queries structural fields at the same level of the object database to unify specifications, development and maintenance. The operation of the database at the application layer of this system adopts the same API specifications.

This service allows developers to deploy back-end environments, code to cloud services, eliminate the need to set up, maintain, expand, manage, and provide services endlessly.

3.6 Cloud Firestore for Firebase

Firestore is a flexible and extensible NoSQL database that can synchronize data between client applications through a real-time listener, and provide offline support for APP and web applications. Whenever the data that the client application is listening to changes, the system will notify through a snapshot of the data and only retrieve the new changes. By employing Firestore we can modify the database only in response to new physiological data in the care system, without tthe need to significantly reset and modify the entire system back end. At the same time, it has the ability to trigger events on the database backend. When the sensor collects new data, the front end web page and app screen can be actively updated by the back end, without the front end actively refreshing, significantly reduce the use of front end performance, and can load a larger amount of IOT care sensor data for visualization.

3.7 Cloud Storage for Firebase

The storage space of this system is not only for accessing media files such as images, audio, video, etc. Compared with well-known cloud storage spaces such as Google Drive, cloud storage can be more flexible in choosing plans such as charging and data retention time based on usage. And there are multiple SDKs to easily integrate different systems. At the same time, the follow-up of this research will introduce how to extract and transpose the Firestore object data for analysis later. Cloud storage can be flexibly integrated with other cloud services without unnecessary development costs, and it can synchronize the organized data to cloud storage.

3.8 Cloud Pub/Sub

The publish & subscribe mode is an instant messaging service that allows information to be transferred between different applications.

3.9 Cloud Dataflow

Dataflow is a fully-hosted, high-speed, integrated streaming and batch data processing service that minimizes latency, processing time, and costs by automatically scheduling resources and batch processing functions. In addition, there is no need to rely on a server when deploying and managing resources, so this research uses the Dataflow service to subscribe to the pubsub topic to extract and convert each history record in the database into a json file and store it in cloud storage for subsequent data transposition.

3.10 Cloud Dataprep

Cloud Dataprep is a smart data service that uses a visual interface to easily explore, clean, and prepare structured and unstructured data for data analysis, reporting, and machine learning operations.

In this research, Dataprep was used to automatically convert the data extracted by dataflow, format, clean, label, and combine the live data of different objects collected by fixed devices and wearable devices so that subsequent research can focus on analyzing the data.

3.11 BigQuery

BigQuery is a serverless enterprise data warehousing service from Google that not only has high scalability, but also excellent cost-effectiveness, which can help improve our data analysis work efficiency (O. Dawelbeit and R. McCrindle, DC, 2016).

BigQuery is based on a custom schema and data from object storage and spreadsheets, thus it can create a logical data warehouse, and analyze all batch and streaming data. In this study, batches of table data in the custom view model format were transferred from Dataprep to BigQuery for large-scale IOT device data streaming storage and analysis.

3.12 Cloud Data Studio

This research uses Google's data visualization tool Cloud Data Studio, which is a system's big data statistics report UI service, to create custom visualizations by turning data into compelling visual content and reports. We link Data Studio to a BigQuery by transposing dataset in advance via Cloud Dataprep. With BigQuery BI Engine the system can get analysis in a very short time.

4 EXPERIMENTAL STEPS AND DATA

4.1 Experimental Field Environment

The experimental field is a 45 x 31 meters area located on the 7th floor of the Tzung-He hall, which is in the National Taipei University of Technology. The 31 Bluetooth light source devices (bNodes) are subordinated as shown in “Figure 8”. Google Home Nest Mini are set in the center of room 709-2 and 709-3. Experiments were conducted every day for 10 days from 1:00 to 6:00 pm, and data on personal behavior patterns were recorded in the database.

Figure 8: Experimental field plan & bNode installation location.

In this experiment, we obtained a total of 11938 row data of tag-records of mobile devices; a total of 10594 row data of device-records; 200 row data of people-records; 250962 raw data of Bluetooth watch records; and test the Google Home Mini by using 13504 unusual data. The statistics are shown in Table.1. As People-records is an individual's behavioral statistics for the day, there will be only one piece of historical data per day.

The design of the experimental data objects and the meaning they represent will be explained in the next paragraph.

Table 1: 10-day experimental data quantity.

Data field	Numbers of row data
Tag-records	11938
Device-records	10594
People-records	200
Bluetooth watch records	250962
unusual data	13504

4.2 Data Model Design

This system database is mainly based on Firestore. The data structure design concept is permission security, optimized query, and reuse. “Figure 9” is the Firestore database object design diagram which is presented in the form of a multi-tree. The following are the object structure nodes definition:

- Personal-account: Record user account, phone, permissions, device password and setup time, user information covers individuals and organizations.
- Locations: Record one or more addresses.
- Floors: Inherit the address information of the previous layer, multiple floor information, including the latitude and longitude of the floor boundary and the floor plan of this floor.
- Devices: Inherit the information of the previous floor and records the current status of the fixed devices on this floor. The fixed device information includes fire detection devices, seat cushions, pedal mats and reed switches, etc.
- Devices-records: Inherit a fixed device whose content is the contact history information of this device.
- Mobile-devices: To this end, the user's mobile phone or tablet records the alias that the user gives to this tablet or mobile phone and the necessary

information for the push function.

- Mobile-tags: This is a wearable device. The current wearable device of the system is a bracelet, a fixed device that records the current address, floor, movement and contact of the bracelet.
- Tag-records: Record historical information from the previous wearable device and contains positioning latitude and longitude information.
- Messages: It records the content of the message from the web, APP or Google Home Nest Mini, the source informations.
- Peoples: As mentioned in the personal-account, users can be divided into individuals and organizations. When the user is an individual, this node records the current user or the user's family, their current behavior and the wearing device. Nodes record the behavior, physical data, and messages of current employees or caregivers from Google Home Nest Mini and the devices they wear.
- People-records: The inherited parent node records the historical information of a person's behavior physical data, and messages.

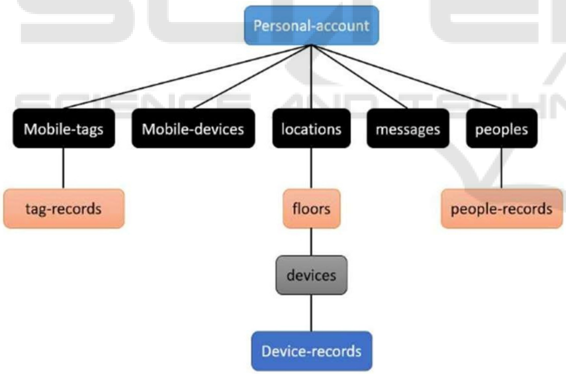

Figure 9: Firestore data structure design.

4.3 Web Monitoring Status

The web is mainly divided into monitoring equipment status, personnel status, and equipment status. Through the webpage, we can instantly monitor the position of personnel and the status of related equipment. “Figure 10” presents indoor positioning information. When an event (fall, fire, break-in, etc.) occurs, the user's location information and floor information can let relevant personnel know.

If the wearable device paired with a related device, after the data is uploaded to the cloud, the user's information will be integrated to know which device the user interacts with, environmental variables are obtained as well, and then keep track of all the above information. That is the user's time, position, and behavioral data are continuously recorded in the database. From “Figure 11”, we can know that the real-time information of the wearers on the day, the currently worn device, and the currently contacted device.

Figure 10: Real-time indoor infographic.

Figure 11: Real-time indoor infographic.

In order to help user, there is also charts and data. From “Figure 12”, we show every users physical data, such as blood pressure, temperature and heart beat rate, in real time.

Figure 12: Real-time physical data.

And create charts (weekly physical data) by click the column of user as shown in “Figure 13”.

Figure 13: Weekly physical data charts.

In addition to the condition of the elderly, this system also cares about the management of a large number of sensors. Therefore, the device list provides this user not limited to a single address floor, but the real-time status of all the devices they own, because there are too many types and numbers of devices. As shown in “Figure 14”, this table provides each field that can be sorted and searched in order, or we can manually search for the device by entering a keyword. The fields are in order: name, type, MAC, altitude, longitude, latitude, status, number of data, setup time, and latest update time.

設備監視狀態

名稱	類型	MAC	...	經度	緯度	...	跟隨的Router	資料...	建立時間	最新更新時間
HL_SMOKEa...	煙霧感測器	0C61CF39AB80	3	121.535862	25.042635	off	546C0EA4F9...	41900	2019-06-18T15:20:24...	2019-07-08 19:41:04.792...
HL_SMOKEe...	煙霧感測器	0C61CF38E608	3	121.535910	25.042627	on	546C0EA4F9...	51122	2019-06-18T15:21:25...	2019-07-08 19:40:59.318...
HL_SMOKEb...	煙霧感測器	0C61CF39B503	3	121.535830	25.042635	off	546C0EA4F9...	49654	2019-06-18T15:18:22...	2019-07-08 19:40:58.825...
UTL_BWRout...	Router	546C0EA4F9BE	3	121.535815	25.042631	off		4899	2019-06-11T13:34:08...	2019-07-08 19:38:52.080...
BLE_CUSHIO...	坐墊	247189F28233	3	121.535875	25.042688	off	546C0EA4F9...	654	2019-07-02T15:32:02...	2019-07-08 19:34:42.633...
BLE_CUSHIO...	坐墊	247189F27330	3	121.535813	25.042688	off	546C0EA4F9...	329	2019-06-26T10:15:11...	2019-07-08 19:27:49.083...

Figure 14: Real-time device infographic.

4.4 Google Home System

We use Google Home as notify system and a way to get points of Elderly Depression Scale to make sure our user are healthy.

As a notify system, we use codes to get the data of physical data when the value is too high or low. And the data will be downloaded, create messages and check the location of user and the nearest Google Home Nest Mini. Then it will push the message to the user.

User can talk to Google Home Nest Mini get their health condition. At the same time, we will ask them some question in geriatric depression scale to make sure their mental health and change the dialog message.

4.5 Data ETL (Extract-Transform- Load)

Except real-time monitoring of the Firestore and web, in order to see the long-term life behavior patterns of the elderly, we will periodically export People-records, Tag-records, Device-records data of the object database through Cloud Dataflow and Cloud DataPrep to set the data recipe. Then Dataprep's graphical interface perform data cleaning, merging, labeling and other data preprocessing actions, as shown in “Figure 15”. Finally, we output personal behavior pattern analysis and statistics Table data into BigQuery database and Cloud Data Studio to link output visual report as shown in “Figur. 16”.

Because People-records data includes the mac address of the wearable device worn by the experimenter on the day. Tag-records data includes the Tag's mac address, the contacted Device mac address and positioning coordinates. Device- records includes the Device's mac address and the contacted event type. We can combine the above three types of historical data records through the above-mentioned ETL data transposition to obtain the experimenter’s long-term who-when-where-which features and behavioral pattern information. In addition to instant notifications of emergency events such as falls and fires, when the behavior of the elderly is too different from past behavioral patterns, the system can also broadcast care reminders, or notify the family to achieve the effect of smart care.

Figure 15: Dataprep Data processing interface.

The advantage of the design in this research system is that data can be passed through fixed DataPrep recipes. Historical data can be ETL repeatedly stored in BigQuery to accumulate big data. There is no need to do data preprocessing all the time. And the Data Studio reports are continuously updated through BI Engine and SQL. In addition to through the filter of Data Studio, we can easily search for individuals or data on specific dates and experimental time intervals for analysis.

Figure 16: Data studio behavioral big data statistics report.

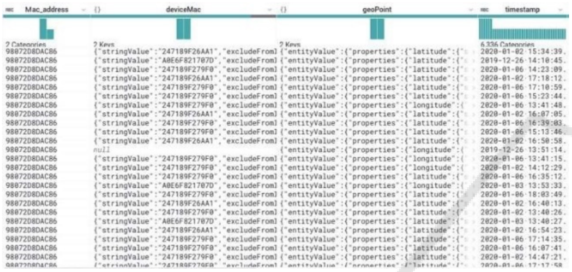

Figure 17: Tag-records data detail.

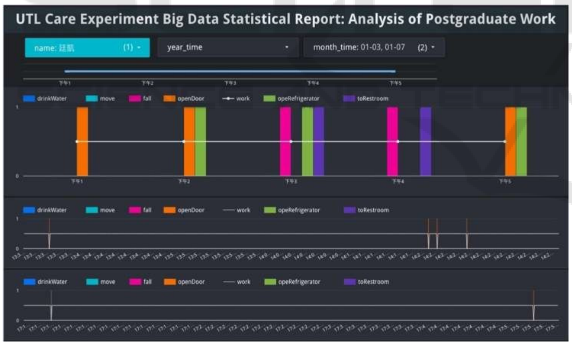

Figure 18: Daily activity pattern of 2 students under test.

According to the statistics of the IOT smart care experiment results based on the above report, it was found that 20 graduate students in this laboratory, 2 of whom were often restless. And in the experiment, each person sat an average of 3.52 hours, went to the toilet 3.4 times, filled water 2.31 times and walked 31.63 meters. If some students have abnormal day activity data in the future, we can take care of his health immediately. Through more tag positioning and access to historical data of the device, such as "Figure 17". We collected tens of thousands of wearer device mac address, contact device mac address, corresponding event actions, positioning coordinates, event time and other data in each experiment, more detailed behavior patterns can be analyzed as shown in "Figure 18". When elderly people living alone have irregular lifestyle habits, they can ask for care or notify the family before the tragedy occurs.

5 CONCLUSION

This study is dedicated to improving quality of people's life. The only solution to deal with and manage the behavior and health of millions of people is big data and Internet of Things technology (Kwok Tai Chui et al., 2019). We hope to use any simple BLE device to automatically sense the surrounding environment and build a smart IOT care system. Therefore, this research uses BLE as the main axis to design, which includes wearable devices, Google Home Nest Mini, magnetic reed switches and other devices. We integrate these with cloud database and big data analysis system. Since the system in this experiment can collect basic sensor data, at the same time, it can collect historical data of absolute positioning of personnel.

Where detailed people go in a day? What action was taken? What time does the elder do with other elders or caregivers in the living room or social room every day? Long-term big data analysis can reveal more detailed life pattern data, and even the social relationships of the elders.

Although we have designed whole system and done some testing, we have still not finished the Google Home System experiment. But we will still work on it, design new data charts and use them to make whole system better. In the near future, through Google Home System, we will provide care, reminders, suggestions and other levels of treatment to elderly proactively.

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