MEDINFO 2017: Precision Healthcare through Informatics
A.V. Gundlapalli et al. (Eds.)

doi:10.3233/978-1-61499-830-3-141

Development of Parkinson Patient Generated Data Collection Platform Using FHIR and IoT Devices

Dae-Young Kim, Sun-ho Hwang, Min-Gyu Kim, Joon-Hyun Song, Sin-Woong Lee, Il Kon Kim

School of Computer Science & Engineering, Kyungpook National University, Daegu, Korea

Abstract

Internet of Things (IoT) devices can be effectively used in cases where continuous observation of patients is required, such as Parkinson's disease. This is due to the characteristics of the IoT (Internet of Things), which allows data to be measured and transmitted at any time, anywhere. In this study, we developed a health data collection platform that stores and transmits the foot pressure data of Parkinson patients using FHIR (Fast Healthcare Interoperability Resources). The platform can be used to collect the foot pressure of a large number of Parkinson's patients. Based on the accumulated data, it is possible to identify abnormal behaviors such as walking pattern, tilt and instability of stride length in patients with Parkinson's disease. Based on the results of this study, accurate diagnosis and treatment of Parkinson 's disease can be made.

Keywords:
Electronic Health Records; Parkinson Disease

Introduction

IoT device can measure various data regardless of time and places. Thus individual who uses IoT devices can easily check and store data. At the same time, the postwar generation starts to retire and preventive medicine has advanced a lot recently. This results in increase of interest in health and desire to manage one's own health data.

Thanks to this situations IoT healthcare device market is growing at rapid pace. IoT healthcare device installation expected to increase greatly from 46 millions in 2015 to 161 millions in 2020 [1]. With this, absolute amount of data measured by IoT healthcare device is growing fast

This is consistent with the current situation in which big data and machine learning are in the spotlight. However, the absolute amount of health data has increased, but there are very few data that can actually be used for big data and machine learning.

The main reason for this is the absence of a standard health data collection platform. Some manufacturers collect health data which is measured in their products through their own cloud services, but their system rarely follow international standards.

Machine learning and big data are very sensitive to data types and formats. If health data collection platform collects data without using a international standard, data from the platform can not be used for machine learning and big data because most of user of the platform enters data without conforming to the data type and format specified by the platform.

Health data collection platform with FHIR can solve these problems above. It's easier to inform platform users with FHIR because it's international health data standard. Validation of data is possible with FHIR, so it is possible to sort out data that does not conform to the standard and obtain good quality data. As a result, this guarantees health data interoperability.

In this study, we would like to develop a standard platform that collects and stores health data measured by IoT healthcare de- vice and provide anonymized data by RESTful API method. To this end, we adopted the FHIR, which is being developed as a next-generation medical information standard in HL7, as a data transmission standard. We anonymized health data because it contains sensitive personal information. We hope that this anonymized health data can be used in various studies. In order to actually apply this platform, we collected health data measured by the foot pressure sensor.

The foot pressure sensor is used to identify patterns of behavior such as abnormal stride and tilt in Parkinson's patients. The measured data can be used to compare the patient's foot pres- sure data with the patient' s condition. A steady state analysis of Parkinson's patients and ongoing feedback are helpful in im- proving the patient's abnormal behavior pattern [2].

In this study, we also present how the standard platform can contribute to continuous observation and feedback of Parkinson's patients. Based on this, we would like to show how a health data platform can provide services to data providers.

Methods

Related Studies

HL7 has been developing FHIR (Fast Healthcare Interoperabil- ity Resources) as a next-generation medical standard. FHIR is suitable for IoT devices and wearable healthcare devices with low processing power due to less usage of data used for health data transmission than other medical standards such as CDA [3].

LOINC is common language for clinical and laboratory observation. It's aim is to provide universal codes and names that provide the global lingua franca for identifying tests and obser- vations [4].

HAPI FHIR is an open source FHIR library led by the University Health Network. This is a Java-based library, so it works well with the Java Spring framework.

When disclosing data, personal identification information such as social security number or name must be removed to protect privacy. The data anonymization method can be classified into simple anonymization through elimination of semi-identifiers, heuristic anonymization in which detailed information is hidden through some rule or human judgment of the values corresponding to semi-identifiers, anonymization through privacy model and algorithm [5].

Foot pressure sensor : Parkinson's disease is accompanied by several abnormal behaviors (slow motion, faceless face, etc.) due to the loss of neurons in the brain [6] In addition to biopsy, behavioral analysis can briefly confirm the patient's condition. We developed and applied a foot pressure sensor to monitor the abnormal behavior pattern for a long time and to identify the gait that can form more accurate diagnosis and prescription through big data formation for the patient.

Health data collection platform

IoT healthcare devices can measure various types of health data. Examples of data that can be measured include Pulse and Oxygen in Blood (SPO2 and Heart rate), Electrocardiogram (ECG), Blood pressure, Electromyography (EMG), Glucometer, Body temperature etc. In this study, the foot pressure was measured and applied to a standard platform.

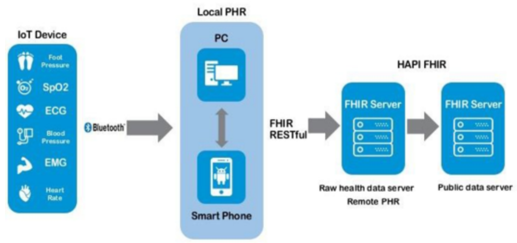


Figure 1- platform overview

An overview of the standard health data collection platform is shown in picture above. The platform consists of IoT Device, Local PHR, Raw health data Server (Remote PHR), and Public data Server.

IoT devices are connected to a PC or smartphone that acts as a local PHR via Bluetooth to transmit measured health data. The user can send the data stored in the local PHR to his raw health data server with his consent. Local PHR generates user health data in FHIR standard format and transmits data to Raw health data server. When converting health data into FHIR format, LOINC code was used as a standard for measured values and measurement positions.

Raw health data server acts as a remote PHR repository. The user can store and query health data only for his / her data, and the server provides functions for this to the RESTful API. Then the raw health data stored by the user is transferred to the public data server through the anonymization process.

In this study, data is anonymized by simple anonymization by removing the quasi-identifier. We generated a random string of 14 digits consisting of integers from 1 to 9 and letters a to z and used it as an identifier for the anonymous user (ISO/TS 25237:2008 Health informatics - pseudonymization). The original identifier and the identifier that is being anonymized are managed as a separate table in the database of the raw health data server. This allows the measurement data for the same user to be continuously updated.

Then, public data server converts the health data stored in an anonymized form into the FHIR format and then releases it to the public through the RESTful API.

Both Raw health data server and public data server were developed as Java Spring framework on Heroku cloud service and HAPI FHIR Library is used for manipulating FHIR resources.

Foot pressure sensor

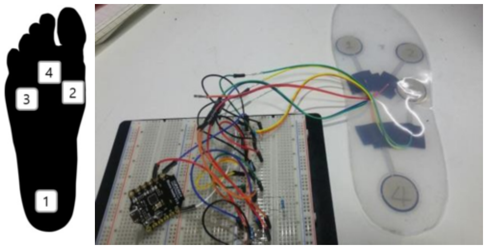


Figure 2 - foot pressure sensor structure

The foot pressure sensor is attached to the sole of the shoe by four pressure sensors, and the user's foot pressure is self-measured. The position of each sensor is shown in Figure 2 [7].

The pressure data measured at the foot pressure sensor is stored in the Android application, which is the patient's local PHR repository. The stored data is converted to the FHIR format when the user agrees, and then transmitted to the Raw health data server.

Foot pressure data of 10 healthy persons and virtual foot pressure data of 10 patients with Parkinson's diseases were measured using a foot pressure sensor. The gait of patients with virtual Parkinson's diseases was measured by imitating the gait by referring to the article [8] that studied the characteristics of the gait of the patient with Parkinson 's disease. Each individual walked 10 seconds on a plain without slope and transmitted foot pressure data to the Raw health data server at 0.1 second intervals.

In order to store the measurement data in the Raw health data server, it is necessary to store the measurement data after registering the patient's basic information. Patient information uses Patient resource of FHIR and measurement data uses Observation Resource. The Raw health data server then anonymizes the data and sends it to the public data server.

Parkinson analysis from foot pressure data provided as public data

The public data server uses the Bundle Resource of the FHIR to provide public data in chronological order. Researchers studying Parkinson's disease can use anonymized user information and foot pressure data from a public data server in a variety of ways.

In this study, we derived data on the order of movement of the center of gravity and the distribution of plantar pressure from the foot pressure of anonymous Parkinson's patients and healthy persons. The center of gravity according to the movement was compared with the time when the first pressure was applied to the four sensors, and the pressure distribution of the sole was compared with the intensity of the pressure applied to each of the four sensors. As a result, we could find the difference between the foot pressure change and the foot pressure distribution in general and Parkinson's patients.

Provide services to the patient based on the analyzed data

To provide an example of the use of health data collection plat- form, we have developed an application that provides a service to compare the data of Parkinson's patients and the general public based on the above analysis and to analyze the progress of the treatment.

The application compares and analyzes the foot pressure data from the IoT healthcare device of Parkinson's patients against the general foot pressure data provided by the public data server. On the basis of this, the medical staff can know the cur- rent condition through the self-measurement of the patient, and can simply summarize the opinion on the progress of the treatment compared with the past patient's record. In case of an emergency, user can contact the doctor in charge. The information on the treatment progress and the bio-signal is stored in the local PHR repository so that the physician and the guardian can read it at any time.

Results

The FHIR Patient resource is generated to transfer patient in- formation from the local PHR to the Raw health data server is as follows.


```
{
  "resourceType":"Patient",
  "identifier":[{
       "value":"910523-2895112"
  }],
  "name":[{
       "use":"official",
       "family":[
          "Anderson"
       ],
       "given":[
          "Rollingstone",
          "K" ] }],
  "telecom":[{
       "system":"phone",
       "value":"01057524885",
       "use":"work" }],
  "gender":"male",
  "birthDate":"1991-05-23"
}
```


Figure 3 - Patient resource

The resident registration number was used as an identifier of the patient and basic information such as name, phone number, sex, date of birth, etc. was stored.

Observation resource is generated to send the foot pressure measurement data from the local PHR to the raw health data server.

The patient identification number was used to identify the measurement value of the patient and the data was stored in chronological order including the measurement time. The Loinc code for the Body site and Component is not mapped yet.

Public data server uses FHIR Bundle resource to provide the anonymized foot pressure data measured at the foot pressure sensor. Due to the characteristics of the Bundle resource, multiple components can be stored, allowing the researcher to transfer large amounts of health data at a time.


```
{
  "resourceType":"Observation",
  "id":"foot-pressure",
  "identifier":[{
       "value":"910523-2895112" }],
  "effectiveDateTime":"2016-10-30T11:23:21+06:00",
  "bodySite":{
    "coding":[{
        "system":"",
        "code":"",
        "display":"Right foot sole" }]},
  "component":[{
       "code":{
         "coding":[{
             "system":"",
             "code":"",
             "display":"foot pressure sensor 1" }]},
       "valueQuantity":{
         "value":116,
         "unit":"lb"}}]
}
```


Figure 4 - Observation resource

FHIR StructureDefinition resource describes a structure - a set of data element definitions, and their associated rules of usage. This resource is used to describe the underlying resources, data types defined in FHIR, and also for describing extensions, and constraints on resources and data types.

The base FHIR specification describes a set of base resources, frameworks and APIs that are used in many different contexts in healthcare. However there is wide variability between jurisdictions and across the healthcare ecosystem around


```
<?xml version="1.0" encoding="utf-8"?>
<StructureDefinition xmlns="http://hl7.org/fhir">

…

<base
value="http://hl7.org/fhir/StructureDefinition/Patient" />
  <differential>
    <element>
      <path value="Patient" />
      <type>
        <code value="Patient" />
      </type>
    </element>
    <element>
      <path value="Patient.identifier" />
      <definition value="An identifier for this patient" />
    </element>
    <element>
      <path value="Patient.identifier.id" />
      <representation value="xmlAttr" />
      <definition value="unique id for the element within a
resource (for internal references)" />
    </element>

…

  </differential>
</StructureDefinition>
```


Figure 5 - Patient StructureDefinition

```
<?xml version="1.0" encoding="utf-8"?>
<StructureDefinition xmlns="http://hl7.org/fhir">

…

<base
value="http://hl7.org/fhir/StructureDefinition/Observation"
/>
<differential>
    <element>
      <path value="Observation" />
      <type>
        <code value="Observation" />
      </type>
    </element>
    <element>
      <path value="Observation.identifier" />
      <definition value="A unique identifier for the simple
observation instance" />
    </element>
    <element>
      <path value="Observation.identifier.value" />
      <definition value="The portion of the identifier typi-
cally displayed to the user and which is unique within the
context of the system" />
      <exampleString value="123456" />
    </element>

…

  </differential>
</StructureDefinition>
```

Figure 6 - Observation StructureDefinition

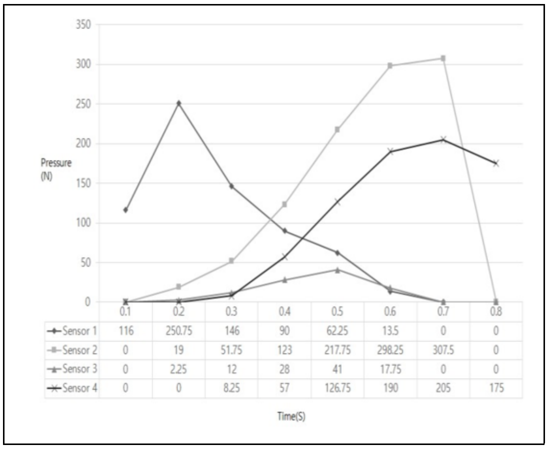
practices, requirements, regulations, education and what actions are feasible and beneficial. For this reason, further adaptation is required to particular contexts of use.

As a consequence, StructureDefinition resources for Patient and Observation resources are defined are outlined in Figures 5 and 6.

These two StructureDefinition resources not only represent a structure constrained or extended from basic FHIR specification, but also can be used to validate FHIR resources being ex- changed for the purpose of enhancing the degree of interoperability.

Data were provided as shown in Figure 6 and Figure 7 with public health data on foot pressure. We record the point at which the pressure value applied to the foot pressure sensor initially has a value at the initial value (0) to analyze the pattern of the gait pattern. In general, the pattern of walking changes regularly from 1 → 2 → 3 → 4, but the patterns of Parkinson's patients are not known because Parkinson's pressure is applied in an irregular order [9]. We found differences in gait patterns among the general population and Parkinson's patients. Also, by comparing the pressure of each sensor at the same time, the difference in foot pressure distribution between the general and Parkinson's patients was also found.

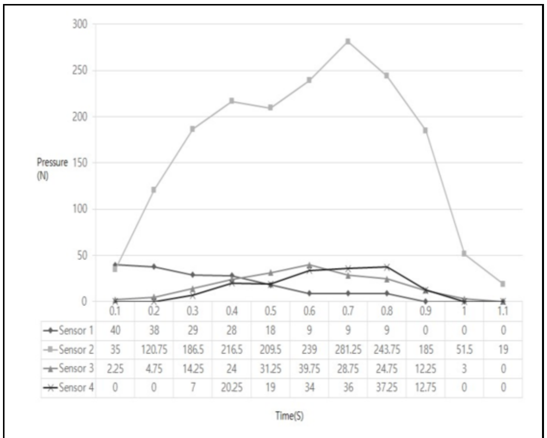
Figure 7 is a graph of the mean of the pressure values applied to the four sensors over time while a person is walking. In the case of a normal person, we can see that the movement of weight is sequentially performed from sensor No. 1 to sensor No. 4.



Time(S)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Sensor 1	116	250.75	146	90	62.25	13.5	0	0
Sensor 2	0	19	51.75	123	217.75	298.25	307.5	0
Sensor 3	0	2.25	12	28	41	17.75	0	0
Sensor 4	0	0	8.25	57	126.75	190	205	175

Figure 7 - Steps of healthy person

Figure 8 is a graphical representation of the mean value of pres- sure applied to four sensors over time while a Parkinson patient is walking. In the case of Parkinson's patients, pressure is uni- formly applied to the remaining sensors except the second sen- sor. This can be interpreted as an unusual step where the center of gravity is constantly biased forward. Using the difference in gait patterns of these patients, the current state of the patient can be diagnosed by comparing with the normal control group.



Time(S)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1
Sensor 1	40	38	29	28	18	9	9	9	0	0	0
Sensor 2	35	120.75	186.5	216.5	209.5	239	281.25	243.75	185	51.5	19
Sensor 3	2.25	4.75	14.25	24	31.25	39.75	28.75	24.75	12.25	3	0
Sensor 4	0	0	7	20.25	19	34	36	37.25	12.75	0	0

Figure 8 - Steps of Parkinson's patient

Discussion

Using the health data collection platform developed in this study, a large amount of accumulated health data can be utilized by researchers and medical personnel in various researches. Our ultimate goal is to provide beneficial services based on the results of research using this platform, and to contribute to the promotion of human health.

From this point of view, applying this platform to actual Parkinson's patients is expected to provide customized services to patients with Parkinson's disease based on the results of using the foot pressure data. The mobile application can help patients to quickly identify their condition, instantly adjust the supply of drugs under test, and help them improve treatment methods, such as understanding the course of treatment based on objective health data.

In order to implement this, there are additional things to be to the platform : linkage between hospital system and raw health data server, advanced data anonymization algorithm.

Improvements in terms of IoT devices include measuring heart rate, blood oxygen saturation, EMG, blood pressure, and various other health data to enable more comprehensive patient sta- tus confirmation.

As these improvements are implemented and the actual data of Parkinson patients are constantly accumulated on the platform and enough data is formed, it is possible to make more advanced research and diagnosis. Based on this, it will be possible to perform gait correction and early diagnosis of Parkinson's disease and correct treatment can be done.

Conclusion

The reason why many health data are not used in the medical field is that the health data is collected without using the international standard. If the data is collected without conforming to the international standard, it is impossible to verify the input data, and the collected data shows increased errors. In addition, all does not share standards set up individually, so additional processing of the data is required when the data is utilized be- cause of the lack of versatility.

To solve this problem, this study proposed health data collection platform that collects and provides health data using FHIR, the next generation medical standard. In order to apply the plat- form to the medical field, we dealt with patients with Parkinson's diseases and measured the patient 's footsteps through the foot pressure sensor.

Acknowledgements

This study was carried out as a result of the research project of Ministry of Science, ICT and Future Planning, Institute for Information & communications Technology Promotion and SW centered university (R2215-16-1004)

This work was supported by the Future Flagship Program(10053249, Development of Personalized Healthcare System Exploiting User Life-log and Open Government Data for Business Service Model Proof on Whole Life Cycle Care) funded by the Ministry of Trade, Industry & Energy(MOTIE, Korea).

References

[1] Tratica, *Healthcare Wearable Device Shipments to Reach Million Units Annually by 2011,* April 14, 2016

[2] E.J. Protas, Gait and step training to reduce falls in Parkinson's disease, *NeuroRehanilation* (2005), 183-190.

[3] B.Franz, A. Schuler, and O. Krauss, Applying FHIR in an Integrated Health Monitoring System, *EJBI* **11** (2015), 51-52.

[4] About LOINC, Available at: http://loinc.org/background

[5] Y. Kwon, J. Yeon, and S. Lee, Anonymization Techniques Suitavle for Real Medical Datasets, *Proceedings of the Korean Information Science Society Conference Volume* **38** (2011), 80-83.

[6] Division of General Internal Medicine, University of California, San Francisco (UCSF), School of Medicine 94143- 0320, USA, Parkinson's disease diagnosis and treatment, *Western journal of medicine* (1996), 234-240.

[7] S.J. Morris, Shoe-Integrated Sensor System for Wireless Gait Analysis and Real-Time Feedback, Proceedings of the Second Joint EMBS/BMES Conference, (2002).

[8] J. Chae and H. Cho, The Research of Gait on Parkinson's Disease, *Journal of the Korean Society of Physical Medicine* **4**(4) (2009), 249-255.

[9] S. L. Joon and S.L.D-K. Shin, Features Extraction for Classifying Parkinson's Disease Based on Gait Analy, *Korean Society for internet information* **11**(6) (2010), (13-20).

Address for correspondence

Il Kon Kim. Professor, Computer Science and Engineering Graduate School, Kyungpook National University, Daegu, Korea Republic of, E-mail: ikkim@knu.ac.kr