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A Cost Evaluation Model for Developing FHIR-based Health Information Services to Support Massive Clients

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Abstract

Healthcare services converged with ICT technology are improving quality of life and satisfaction through various customized services. In ICT-based medical services, data interchange between medical services is important, and HL7 FHIR, a medical data standard, enables efficient medical data interchange. FHIR-based medical information services using wireless data broadcasting can efficiently support massive clients. This paper proposes a function point model to evaluate the implementation cost of FHIR-based health information services using wireless data broadcasting. The proposed cost evaluation model can effectively evaluate the development cost by applying the complexity of converting medical data into FHIR format and the complexity of organizing indexes to efficiently support massive clients. The comparison of the proposed feature point evaluation model with simple feature points shows the efficiency and suitability of the proposed cost evaluation model.

Keywords: *Cost Model, Function Point, FHIR, HL7, Information Service.*

1. Introduction

Advances in medical technology have increased life expectancy and improved quality of life, and convergence with ICT technology has led to the development of various medical services that increase user satisfaction. In particular, mobile and wearable technologies allow individuals to collect their own medical information and use it for third-party medical services, enabling a variety of customized medical services. In ICT-based medical services, data interchange between medical services is important. [1, 2]

Fast Healthcare Interoperability Resources (FHIR) of Health Level 7 (HL7) is a document-based health information exchange standard that facilitates the exchange of health information through web services. FHIR is characterized by the organization of health information into resources, which makes it easier to structure health information and faster to exchange health information. FHIR resources have a wide range of applications, as they not only facilitate the exchange of medical information between medical services, but also allow individuals to collect medical information and receive third-party services using it [3, 4].

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Because wireless data broadcasting can deliver data to any number of clients, systems that provide FHIR-based health information services using wireless data broadcasting can efficiently deliver FHIR resources to a great number of clients. Figure 1 shows a system that converts medical information from a hospital's electronic medical record (EMR) system into resources via an FHIR server and then broadcasts them to a wireless channel via a wireless data broadcast server. Here, the broadcast system broadcasts the FHIR resources generated by the FHIR server to the wireless channel, and clients can access the wireless channel to download the resources they want [5, 6].

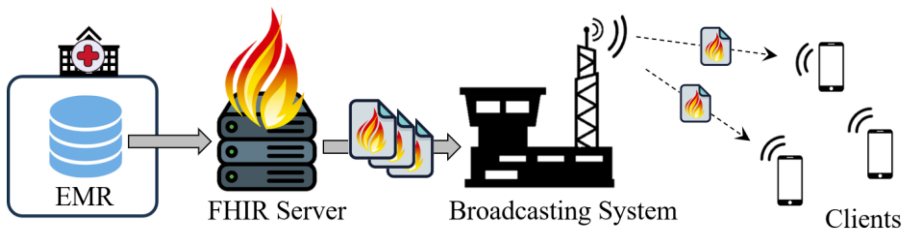

Figure 1. FHIR-based health information services to support massive clients

In this system, the process of converting EMR data to FHIR and the organization of indexes that allow clients to efficiently access FHIR resources over the air have a significant impact on system performance. For the successful development of this system, it is very important to estimate the appropriate cost of not only the design but also the implementation. Various models are used to evaluate the development cost of software systems, among which the Function Point (FP) model is an effective cost estimation model that evaluates the development cost centered on the functionality of the software [7, 8].

In this paper, we propose a function point model to evaluate the implementation cost of a wireless data broadcasting system that provides FHIR-based efficient healthcare services to a great number of clients. This paper reviews FHIR resources as related work in Section 2. We propose a function point model for evaluating the cost of developing a wireless broadcast system based on FHIR resources in Section 3. The efficiency and suitability of the proposed feature point model is evaluated in Section 4, and the paper concludes in Section 5.

2. Related Works

2.1 HL7 FHIR

HL7 FHIR is a next-generation standard framework for health information exchange that uses RESTful APIs to exchange health information over the web. The DSTU2 version of FHIR was released in September 2015 and is constantly being updated to address issues in healthcare information exchange. FHIR organizes medical information into resource units and exchanges documents and messages of those resources using RESTful APIs to enable faster exchange of medical information in a simpler format than existing methods. Since medical information is organized into resource units, FHIR enables to select only the necessary resources to organize the medical information to be exchanged. The advantage of using link information is that one resource can refer to various resources, enabling flexible exchange of medical information. Figure 2 shows the process of resource management and medical data exchange using FHIR [3, 4, 9, 10].

Figure 2. Resource management and healthcare data exchange (https://hl7.org/fhir/)

3. Functional Point Model for FHIR Based Broadcast System Development

3.1 Function Point Model

The function point model for software development cost estimation follows the procedure shown in Figure 3 below.

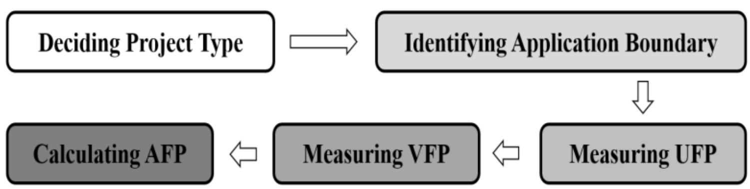

Figure 3. Procedures for estimating function points

1) Determine project type and identify application boundaries
Software cost estimation measures functional points based on the type of development project. Project types are categorized into development projects, enhancement projects, and completed applications. The project type determines the scope for measuring functional points. The next step is to identify the boundaries of the application in order to measure the feature points for the determined project type. At this stage, all features provided by the application are included in the scope of measurement and all logical functions are identified.

2) UFP Measurement
Unadjusted Function Point (UFP) is a factor that evaluates the data function and transaction function and is evaluated using the following equation (1).

$$UFP = \sum (V_{ILF}, V_{EIF}, V_{EI}, V_{EO}, V_{EQ}) \quad (1)$$

Internal Logical Files (ILF) and External Interface File (EIF) are elements that evaluate data functions, while External Input (EI), External Output (EO), and External Query (EQ) are elements that evaluate transactional functions. ILF is evaluated by the number of files for logically identifiable data or control information of the software. ELF is measured by the number of files the software references during execution. ILF and EIF are measured using DET, the number of unique fields in each file, and RET, the number of records. Table 1 shows DET and RET.

Table 1. Matrix for ILF and ELF

		DET		
		1 to 19	20 to 50	over 51
RET	1	Low	Low	Average
	2 to 5	Low	Average	High
	over 6	Average	High	High

EI, a factor for the track transaction function point, refers to the complexity of the control information and unit processes that are input into the software system from the outside. EI is measured using DETs and File Type References (FTR), which represent file types. Table 2 shows the DETs and FTRs for evaluating EI.

Table 2. Matrix for EI

		DET		
		1 to 4	5 to 15	over 16
FTR	0 to 1	Low	Low	Average
	2	Low	Average	High
	over 3	Average	High	High

EO refers to the function points for the processes that are processed by the software in the system and go out as output and is measured using the DET and FTR shown in Table 3. EQ is the function point for the query process that is processed by the software system and is measured using the DET and FTR shown in Table 3, just like EO.

Table 3. Matrix for EO and EQ

		DET		
		1 to 5	6 to 19	over 20
FTR	1	Low	Low	Average
	2 to 3	Low	Average	High
	over 4	Average	High	High

3) VFP Measurement

The general functionality of a software system is evaluated using the Value Adjustment Factor (VAF). VAF is measured using General System Characteristics (GSC). Table 4 shows the 14 items of GSC. Each factor of the GSC has a value from 0 to 5 and is called the Degree of Influence (DI) shown as Table 5.

Table 4. General System Characteristics

GSC		Value
G_1	Data Communication	DI_1
G_2	Distributed Data Processing	DI_2
G_3	Performance	DI_3
G_4	Heavily Used Configuration	DI_4

G_5	Transaction Rate	DI_5
G_6	Online Data Entry	DI_6
G_7	End-User Efficiency	DI_7
G_8	Online Update	DI_8
G_9	Complex Processing	DI_9
G_{10}	Reusability	DI_{10}
G_{11}	Installation Ease	DI_{11}
G_{12}	Operation Ease	DI_{12}
G_{13}	Multiple Sites	DI_{13}
G_{14}	Facilitate Change	DI_{14}

Table 5 Degree of Influence

Value	Meaning
0	No influence
1	Incidental influence
2	Moderate influence
3	Average influence
4	Significant influence
5	Strong influence throughout

The VAF is measured using Equation (2) as the DI value of each item in the GSC.

$$VAF = 0.01\sum (\mathrm{DI}_i) + 0.65 \qquad (2)$$

4) AFP Measurement
The Adjusted Function Point (AFP) is the overall function score of a software system, which is the UFP adjusted by the VAF. Using the UFP and VAF, AFP is calculated using the following equation (3)

$$AFP = UFP \cdot VAF \qquad (3)$$

3.2 Function Point Model for FHIR-based Health Information Broadcasting Service

In FHIR-based health information broadcasting services, data conversion of existing medical information into FHIR format and construction of broadcast index for quick access of FHIR data are important factors for efficient services. Therefore, a function point model for cost evaluation of FHIR-based health information broadcasting service development must include these two factors. We propose a function point model, FhirFP, that applies the two mentioned elements.

1) Function Point for FHIR Data Conversion
FhirFP applies CFHIR, which stands for FHIR data conversion complexity, to reflect the impact of FHIR data conversion on development costs. Because CFHIR is related to transactions that process data, it should be treated as one of the transactional features, and the value of CFHIR has one of the following values: Low, Average, and High like other transactional feature points. The UFP of FhirFP is measured using Equation (4), and the complexity of each element for measuring UFP is shown in

Table 6.

$$UFP_{FhirFP} = \sum (V_{ILF}, V_{EIF}, V_{EI}, V_{EO}, V_{EQ}) + N_{CFHIR}\cdot CFHIR$$
$$= N_{UF}\cdot ILF + N_{EI}\cdot EIF + N_{UI}\cdot EI + N_{UO}\cdot EO + N_{UQ}\cdot EQ + N_{CFHIR}\cdot CFHIR \quad (4)$$

Here, N_{UF} is the number of user files; N_{EI} is the number of external interfaces; N_{UI} is the number of user inputs; N_{UO} is the number of user output; N_{UQ} is the number of user queries; N_{CFHIR} is the number of the resources of FHIR;

Table 6. The Complexity for UFP for FhirFP

Value	Complexity		
	Low	Average	High
EI	2	4	6
EO	4	7	10
EQ	3	5	8
ILF	6	11	17
EIF	5	8	12
CFHIR	5	10	18

2) Function Point for FHIR Data Index Configuration

FhirFP applies a feature point DI_{IDX} for FHIR data index configuration to reflect the impact of FHIR data index configuration on development costs. Since DI_{IDX} can be viewed as one of the normal functions handled internally by the system, it should be applied as a factor to measure VAF. The VAF of FhirFP with DI_{IDX} applied is measured using Equation (5).

$$VAF_{FhirFP} = 0.01(\sum DI_i + DI_{IDX}) + 0.65 \quad (5)$$

where $\sum DI_i$ is the sum of the values using the 14 entries of the GSC of the FP.

The AFP for FhirFP is the sum of the UFP measured by Equation (4) and the VAF measured by Equation (5).

4. Evaluation of the Proposed Function Point Model FhirFP

To demonstrate the effectiveness of proposed FhirFP for development cost estimation for health information services supporting a great number of clients, we compare FhirFP with a simple FP model. We also evaluate the estimated time required to develop an application using FhirFP and FP to compare the suitability of the proposed models. Tables 6, 7, and 8 show the values of the metrics used in the evaluation. CFHIR in Table 6, N_{CFHIR} in Table 7, and G_{15} in Table 8 reflect the characteristics of large-scale health information services applied to FhirFP.

Table 7. The value of parameters for UFP

Parameters		Value
N_{UI}	The number of user inputs	30
N_{UO}	The number of user outputs	10
N_{UQ}	The number of user queries	5
N_{UF}	The number of user files	30
N_{EI}	The number of external interfaces	15
N_{CFHIR}	The number of FHIR resources	20

Table 8. The value of parameters for VAF

Parameters		Value
G_1	Data Communication	3
G_2	Distributed Data Processing	5
G_3	Performance	5
G_4	Heavily Used Configuration	4
G_5	Transaction Rate	3
G_6	Online Data Entry	5
G_7	End-User Efficiency	3
G_8	Online Update	3
G_9	Complex Processing	4
G_{10}	Reusability	2
G_{11}	Installation Ease	4
G_{12}	Operation Ease	4
G_{13}	Multiple Sites	1
G_{14}	Facilitate Change	3
G_{15}	Index Configuration	5

4.1 Comparing UFP

Figure 4 compares the UFPs that evaluate the capabilities related to data and transactions in a software system. In Figure 4, the label FP refers to the UFP of FP, FhirFP refers to the UFP of FhirFP, and Low, Average, and High refer to the magnitude of the value of CFHIR, a factor related to the FHIRE conversion. Figure 4 shows that FhirFP is a better and more appropriate cost model for evaluating the cost of a health information system supporting massive clients. This is because FP's UFP does not capture the FHIR conversion, which is an important factor in health information systems. Unlike FP, UFP under FhirFP increases as the complexity of CFHIR increases, reflecting the impact of the increased cost of FHIR conversion.

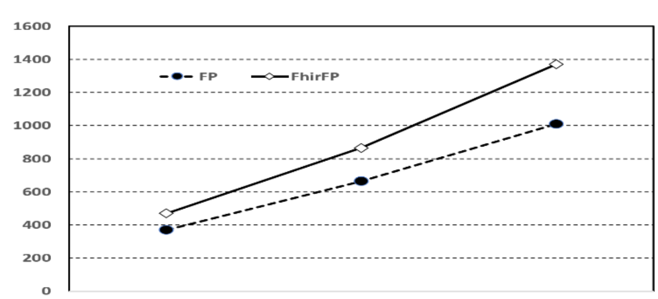

Figure 4. UFP of simple FP and the proposed FhirFP

4.2 Comparing AFP

AFP is the application development cost with UFP and VAF applied. Figure 5 shows the value of AFP by FP and FhirFP. Comparing the value of AFP with the value of UFP in Figure 3, the value of AFP is larger because AFP is the value of VAF applied to UFP by Equation (3). In Figure 5, the deviation between the AFP of the FP and the AFP value of the FhirFP is larger than the deviation between the UFP in Figure 4, because the VAF value measured by the FhirFP is larger than the value by the FP. The VAF of FhirFP has an additional factor for index configuration that supports large clients, indicating that FhirFP is suitable for measuring the development cost of health information systems that support large clients.

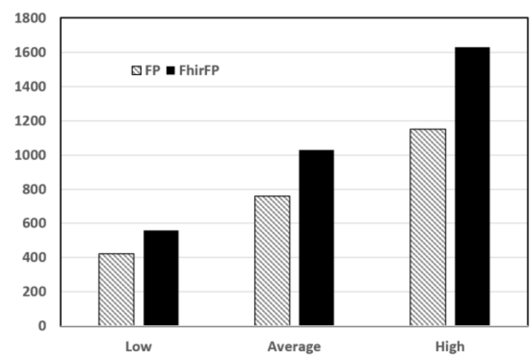

Figure 5. VFP of simple FP and the proposed FhirFP

4.3 Comparing development time estimated using AFP

The estimated time required to develop a software system is measured using Equation (6).

$$T_{EST} = AFP \cdot F_{EST} \tag{6}$$

In equation (6), T_{EST} is the estimated time to develop and F_{EST} is the estimated time per function point. Figure 6 shows the estimated time when F_{EST} is 2.5. Figure 6 shows that the estimated time based on AFP by FhirFP is larger than that based on FP, which is because FhirFP better reflects the characteristics of implementing an FHIR-based health information system than simple FP.

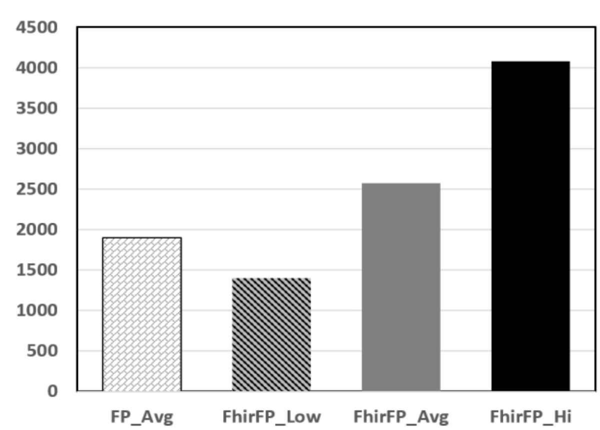

Figure 6. The Estimated Time for Development with AFP

5. Conclusion

In this paper, we proposed FhirFP, a model for evaluating the cost of developing an FHIR-based health information system that effectively supports massive clients. FhirFP applies the complexity for the process of converting medical data to FHIR format to the UFP of the cost model. And the VFP of the cost model has the complexity factor for organizing indexes to efficiently support large numbers of clients. The UFP and VFP of the FhirFP allowed to effectively evaluate the cost of developing a health information system that efficiently supports a great number of clients. To show that the proposed FhirFP is suitable for evaluating the development cost of FHIR-based health information services, the UFP of FhirFP and simple FP were compared, and the development time estimation analysis using AFP and AFP were compared. The evaluation shows that the proposed FhirFP is suitable for estimating the development cost of a service that efficiently supports FHIR-based medical information to a huge number of clients.

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