Evaluating Electronic Health Records Interoperability

Fadoua Khennou[1(✉)], Youness Idrissi Khamlichi[2], and Nour El Houda Chaoui[1]

[1] TTI Laboratory, Higher School of Technology, Sidi Mohamed Ben Abdellah University, Fes, Morocco
{fadoua.khennou,houda.chaoui}@usmba.ac.ma
[2] REIS Laboratory, Faculty of Science and Technology, Sidi Mohamed Ben Abdellah University, Fes, Morocco
youness.khamlichi@usmba.ac.ma

Abstract. Nowadays, ensuring clinical interoperability is considered a challenging situation for health practitioners. This is due to the development of an excessive amount of electronic health record (Ehr) softwares, which do not consider the integration of the interoperability modules at an early stage. Actually, many isolated solutions are present and are unable to exchange data with other systems.

Instead of presenting new distinct solutions in terms of modeling, storage and processing techniques, we need to shed light and upgrade their current capabilities in order to end up with compatible platforms.

In this paper, we formalize and assess the interoperability concept in regards to the health sector. Our approach is an extended version of the legacy Levels of Information Systems Interoperability Model (LISI), which was originally designed in the context of The Joint Task Force (JTF) system. Through this, we define representative metrics that have to be achieved within an Ehr, and classify them according to semantical, syntactic and technological attributes. The model revealed meaningful results in firstly measuring the level of the interoperability then generating a matrix profile able to display the main gaps and shortfalls need to be enhanced so as to attain a mature stage.

Keywords: Clinical interoperability · Electronic health record · Levels of Information Systems Interoperability Model (LISI) · Semantical · Syntactic · Technical

1 Introduction

Electronic health record systems are designed to contain and share information from all providers. Their main purpose is to enable, for physicians and health care professionals, access unstructured data, perform rapid interventions and quality follow-up with their patients.

In addition to that, their integration allows patients and health care providers to securely access and share medical information from their medical records electronically. While an electronic medical record is represented just as a digital version of

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paper, an electronic health record is much more developed and can provide diversified features. From preliminary interviews, diagnostics, follow-up examinations to treatments, the information flow is always present between different Ehrs. The primary goal behind the implementation of these systems is to improve the patients' care, accelerate clinical and diagnostic analysis, manage patient history reports, avoid repetitive laboratory tests and overall boost the quality of care within health organisms.

However, if this implementation is not followed by interoperability solutions [5] to connect hospitals, community laboratories, clinics and other health institutes, so as to facilitate a secure electronic exchange of applications and clinical data, it will be arduous to take advantage from these systems' features and their added value.

That's to say, we must define, study and analyze health interoperability metrics, that will help us examine whether two health systems are interoperable or not. For that, the LISI assessment model [4] has been presented and applied for the health sector in order to measure potential interoperability between systems.

This prototype approach is beneficial for both researchers and health practitioners. Once applied, it will assist them in suggesting improvement and integrate new semantic, syntactic and technological solutions for their Ehrs.

2 Related Work

Peter Drucker said: 'if you can't measure it, you can't improve it'. Actually, the interoperability concept is represented as an abstract term, and because of that many health organisms find difficulties in enhancing it within their Ehr [7]. This has pushed us to think wisely on how to quantify this concept.

Unfortunately, there is a very minimal focus on the implementation of a conceptual model that can formalize and measure the interoperability of some given systems. Those that do exist are based only on implementing very specific technical health standard infrastructures, and do not introduce a comprehensive model that can be applied as a general case study.

Authors in [8], have presented a comparative study of some legacy interoperability models, which are based on the leveling approach. This was mainly introduced by Levels of Information Systems Interoperability (LISI) and Level on conceptual Interoperability Model (LCIM) [12], both of them can be applied for the classification of interoperability in the fields of applications and systems. While the first approach is based on the study of the technological interconnection of interoperating applications, the second focuses only on the conceptual aspect through the definition of data exchange interfaces between the communicating systems. Another leveling based approach that was proposed by ATHENA [9] (Advanced Technologies for Interoperability of Heterogeneous Enterprise Networks and their Applications) is a maturity model that covers business aspects and services within an independent enterprise.

A common drawback that can be noted toward these models, is that they are very limited and did not cover specific modules of interoperability of some actual field of studies such us the healthcare [2]. Yet, even though LISI was conceived in 1990 it has proven to be of considerable value. Introduced by the Department of Defense in the United States of America (DoD), the model proposes not only an interoperability profile but also a platform for measuring and assessing the degree of potential interoperability between systems.

Our main goal throughout this paper is to analyze the methodological process of the LISI model and propose an extended prototype for application to healthcare. To do so, we firstly formalize the concept of interoperability based on semantical, syntactic and technological attributes, evaluate these parameters in regards to the existing systems and generate a system profile matrix. Through this process, we measure the degree of potential data exchange between two given electronic health records and define the major gaps and shortfalls.

The reminder of this paper is presented as follows. Section 3 presents a description of the LISI model and its methodological process. Section 4 describes our proposed extended model for application to healthcare. Section 5 sheds light on the implementation of a case study, for the evaluation of some existing electronic medical records. Finally, Section 6 features a conclusion of the study.

3 LISI Interoperability Model

The Levels of Information Systems Interoperability (LISI) aims at developing an interoperability profile between independent systems, the correlation of these profiles makes it possible to study the degree of potential interoperability between parties. LISI presents a reference model that defines, measures and estimates the level of interoperability that can be achieved between systems.

3.1 The Reference Model

The reference model (Fig. 1) includes five levels of maturity for interoperability, as well as a set of characteristics described below:

- **Isolated Systems:** There is no communication between applications.
- **Connected systems:** Applications are connected electronically in a local network.
- **Distributed Systems:** Heterogeneous applications can exchange data.
- **Integrated systems:** Applications can collaborate in a sophisticated way.
- **Universal systems:** The applications and their data are shared within the same organism or between distributed ones in a developed mechanism.

A classification of the interoperability through the LISI approach, is defined under the PAID abbreviation:

- **P** for procedures, reflects the procedures, approaches and standards used to establish information exchange between systems.
- **A** for applications, describes the applications that permit data exchange.
- **I** for infrastructures, outlines the hardware and network platform that insure the interaction between systems.
- **D** for data, describes the formats, protocols and semantic exchange of data.

The intersection of the presented interoperability attributes and the five levels of maturity, led to the definition of the reference model presented in Table 1.

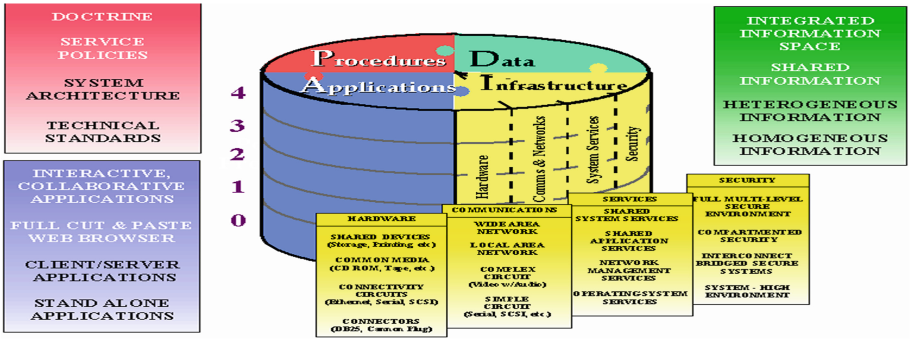

Fig. 1. LISI reference model and its related PAID modules [12]

Table 1. The current LISI reference model (LISI 1998)

Level of interoperability		Interoperability attributes			
		P	A	I	D
4-Enterprise	c	Multi-national enterprise	Interactive (cross application)	Multiple topologies	Cross enterprise
	b	Cross government			
	a	Govt enterprise			Enterprise model
3-Domain	c	Domain level	Groupware	World wide networks	Domain models
	b				
	a				
2-Functional	c	Common operating environment	Desktop automation	Local networks	Program model and advanced data formats
	b				
	a	Program			
1-Connected	d	Standards compliant	Basic messaging	Single connection	Basic data formats
	c				
	b	Site level	System drivers		
	a				
0-Isolated	d	Access	N/A	Removable media	Media
	c				
	b	Control		Manual entry	Private
	a				
	0	No known interoperability			

The background of the PAID concept, was originally conceived in the context of the US task force missions. Each part of the described modules was particularly perceived to enhance system to system interactions. These attributes define a set of components for the commutation of services at each level of sophistication. It helps in specifying the point of weaknesses and gaps within a given architectural system.

3.2 System Profile

The main particularity about the implementation of LISI model lies on its ability to express the outcome, with the calculation of three metrics. These latter allow the definition of the level of interoperability for two operating systems. In this sense, the model assessment was guided by Inspector, a software that was conceived in order to collect and illustrate the features on which two systems could be based on so as to communicate.

The first phase of the process concerns the calculation of a generic interoperability level. This refers to the definition of the highest level of maturity, through which a given system can interact with another one in a specific environment. Hence, we calculate the generic level that has been reached for each parameter of the PAID modules. The second stage reflects the measurement of an expected interoperability level, which is accomplished by comparing two systems' generic level and designating the lowest one. This metric is generally calculated in order to demonstrate the expected level where two systems can operate. At last, a specific interoperability level is needed so as to compare two systems' detailed implementations and features that are checked in regards to the PAID modules.

3.3 System Interoperability Matrix

The final stage of the implementation of the model depicts a matrix, which takes the generic level as a parameter. The intersection of the values for each couple of systems gives rise to the specific interoperability level.

Let's consider an example of an assessment matrix represented in Table 2. The intersection of the generic levels for system D and system C is represented by the specific level 1c. Furthermore, the expected level is calculated by defining the lowest value for both systems, which is also 1c. Here the LISI model indicates that, if the specific level is equal to the expected one, both systems are able to communicate and operate appropriately. However, if the specific level is less than the expected one, then the communication process is limited and there are some actual differences in the features of the examined systems. At last, if the specific level is higher than the

Table 2. Interoperability LISI matrix

Generic Level		**A**	**B**	**C**	**D**	**E**	**F**	**G**
		2a	*1a*	*1c*	*2b*	*3c*	*2b*	*1a*
A	*2a*	2a						
B	*1a*	1a	2a					
C	*1c*	1a	1a	1b				
D	*2b*	2a	1a	**1c**	2b			
E	*3c*	2a	1a	2c	2b	3c		
F	*2b*	2a	1a	2b	2b	1c	2b	
G	*1a*	1a	2a	1a	2a	1a	1a	1a

expected one, we can say that the communication process is very mature and major capabilities of the PAID modules give the qualification to communicate in a high sophisticated level.

4 Proposed Extended Model

In this section, we introduce and analyze the main attributes that define health interoperability, then we describe the process of their integration to the extended prototype based LISI model.

4.1 Health Interoperability Metrics

We can consider an Ehr as interoperable, if it has the ability to operate with other existing or future systems without any barriers. In other words, the interoperability concept is based on a common and explicit understanding of the information exchanged between different partners, and carried out to enable applications exchanging and interpreting information in a homogeneous way. Besides, the workflow has to guarantee an exchange based on three major attributes: semantics, syntax and technology.

Semantic
The aim is to define a common vocabulary that will be used in electronic health records to name a particular medical concept. Semantic interoperability needs to ensure that the exact meaning of the information exchanged is understandable by any other application.

For an electronic healthcare system, this interoperability aspect has to guarantee the development of health reference models, templates and terminologies, allowing formal representation of health data according to international standards.

Reference Model
A reference model combines various assets and health standards, allowing the definition of a common format between several medical organizations. The benefit, is to improve communication, define the scope, the context of health services and enable the re-use for health programs. In this context, several health standards [3] are adopted e.g. HL7, OpenEHR, EN 13606, EN/ISO 12967, HPRIM. Through these, the modeling of clinical data structures such as medical prescriptions, structured documents, blood pressure results and others can be attained with the use of archetypes or special entities, which are designed specifically to accommodate the concepts of health services.

Terminologies and Bindings
This concerns a common modeling of health data types by defining terminology systems for an electronic health record. Coding health data entries is a way of using different terminologies and clinical code domains systems [1] e.g. LOINC, SNOMED CT. As for terminology bindings, it refers to the association of terminology components and an information model of a given health standard. Through this, each terminology set or coded value, which corresponds to specific clinical domains, are

mapped to the information model classes and attributes used to describe a medical concept. In this level, semantic interoperability can evolve by incorporating data from varied systems in one place and interpret exchanged data by its relevant meaning.

Syntactic
This expresses the definition of a common computer formats in order to interconnect various softwares and exchange data. In other words, this requires the definition of a common structure and context between varied medical parties. The syntactic interoperability concerns the way in which data is encoded and formatted. Different formats can be included for sound, photo, image, character encoding, aggregates of several objects and documents formats. In this context, messaging standards are adopted such as Health Level 7, which describes the format for a computerized exchange of clinical data. This leads to the implementation of an open system allowing to assume the heterogeneity of its components.

Technical
Technical interoperability delineates the integration of communication, network protocols and infrastructural technologies. Here, we can define the characteristics of physical medias allowing the storage of the data, its management, security and migration to other supports. It also maintains the replication of records and documents on distant sites.

4.2 Extended Model

As the LISI model demonstrated a broad use of the profiling concept in order to calculate the level of interoperability between systems, the health sector is among the leading industries that requires an interoperable platform [6, 10], which not only supports an information health system, but also a technological platform able to exchange medical data at different levels. In this vein, it is necessary to classify the general attributes defining the interoperability within an electronic health system.

We integrated the interoperability components need to be achieved within an electronic health record system, into the formal model of interoperability LISI. The level of maturity increases according to the attributes related to the semantics, the syntax and the technologies SST used within a health organization. In Table 3, we present our extended LISI model for application to the health sector.

1. **Isolated:** This level describes an initial primitive layer, though which no interoperability can be distinguished. The latter does not define any communication channel and known to be as “not connected”.
2. **Connected:** We considered splitting this layer into two parts. The first concerns an elemental communication process of unstructured medical data records such as: clinical notes, prescription paper charts and discharge summaries. The delivery of these documents is based on a basic platform, which does not support any technological structure. The second one defines a first semantical contextualization of data exchanged between small services of a given health institute.
3. **Functional:** In the third layer, a gradual progression has been demonstrated by an internal local network, allowing a continuous flow of medical data to be stored,

Table 3. The extended prototype of LISI for e-health systems

Level of interoperability			Health interoperability attributes		
			Semantic	Syntactic	Technology
Enterprise	4	b	Multi-national agreement	Cross enterprise model	Multiple topologies
		a	National agreement	Enterprise model	Centralized topology
Domain	3	c	Reference model	Advanced Electronic health records	Security compliance
		b	Terminology bindings	Electronic health records (Ehr)	Metropolitan network (MAN)
		a	Terminologies, ontologies	Domain based data models	Subdomains network
Functional	2	b	Standards compliance	Program model (Emr)	Web based access
		a	Health information system	Advanced data formats	Local network (LAN)
Connected	1	b	Contextualization	Administration data entry support	Single connection
		a	N/A	Clinical notes, prescription paper charts, discharge records, nurse/doctor notes…	Basic messaging
Isolated	0	0	N/A	N/A	N/A

queried and manipulated. This consists of using web services, databases, Electronic Medical Records to store, process and model a Health Information System (HIS).

4. **Domain:** Here we attain a high level of maturity, since we recognize a partial or complete integration of health standards for instance: OpenEHR, HL7, HPRIM and others. The domain level can be earned by implementing an Electronic Health Record using common clinical code domains, health terminologies and ontologies. As for ensuring an integral exchange between different medical domains, we note the integration of security and privacy modules in the Ehr system.
5. **Enterprise:** The last layer allows to define a communication process at a high level. It consists of ensuring a centralized or distributed architecture of several connected Ehr coming from myriad health organizations. Semantically, this can be carried out through a formalization of a national or international standard allowing to regroup major health procedures.

Through the presented prototype (see Fig. 2), we apprehend that in order to communicate at a mature level, it is necessary to acquire procedures, health standards, technologies and primordial methods to meet the three major criterion of health interpretability.

Therefore, this makes it easy to define the current state of a given medical organization and improve it by acknowledging the SST modules.

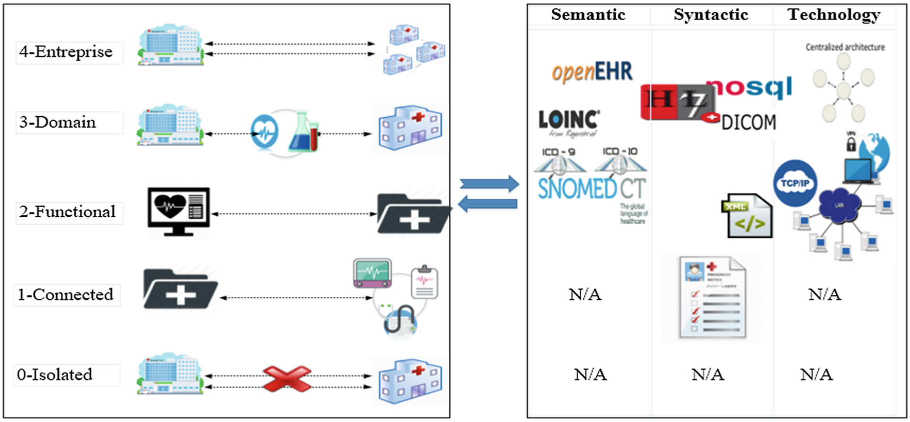

Fig. 2. Extended (SST) metrics for application to healthcare

5 Evaluation

In this part of our paper, we emphasize on the implementation of the described approach, using a case study, in order to measure and evaluate health interoperability of some existing Ehrs.

5.1 A Case Study

The first step is the generation of a generic interoperability profile for each presented system. Table 4 summarizes an interoperability profile generated for the OpenEmr project [11]. This is based on the assessment of the main capabilities (SST) that we previously described for the extended prototype.

Through an in-depth research analysis, we summarized the key features and usage components of OpenEmr and applied them to the extended prototype. As for its generic interoperability metric, it can be calculated by specifying the highest level of sophistication that can be achieved, using the described system's components. In this case, the metric is 3a which is a result of the lowest value of the defined SST (S:3a, S:3a, T:3c).

We applied the same process for a sample of some existing Emrs and Ehrs [13]. Table 5, outlines the results of their reported generic level.

While the generic level measures only the value that corresponds to each particular system, the expected and specific levels calculate the degree by assembling two distinct electronic health records. Meaning, we compare the ability of two systems to operate and exchange data in a specific level of sophistication. Figure 3, displays the generated assessment matrix of the presented Ehrs.

Here, the matrix indicates the specific level of interoperability resulting from the comparison of distinct electronic health records. By doing so, we can summarize the gaps and shortfalls need to be enhanced for each Ehr.

Table 4. The generic interoperability profile (OpenEmr)

Level of interoperability			Health Interoperability Attributes		
			Semantic	**Syntactic**	**Technology**
Enterprise	**4**	**b**	Multi-national agreement	Cross enterprise model	Multiple topologies
		a	National agreement	Enterprise model	Centralized topology
Domain	**3**	**c**	Reference model	Advanced Electronic health records	HIPAA
		b	Terminology bindings	Electronic health records	Metropolitan network (MAN)
		a	ICD-9 ICD-10 SNOMED RxNorm SNOMED	Domain based data models	Subdomains network
Functional	**2**	**b**	Standards compliance	Medical practice management software	HTTP
		a	Health information system	Advanced data formats	Local network (LAN)
Connected	**1**	**b**	Contextualization	Administration data entry support	Single connection
		a	N/A	Clinical notes, prescription paper charts, discharge records, nurse/doctor notes…	Basic messaging
Isolated	**0**	**0**	N/A	N/A	N/A

Table 5. Generic interoperability level of a sample of Ehr systems

Electronic health records		Reported level
A	OpenEmr	3a
B	Cottage Med	2a
C	Gnuhealth	3c
D	HospitalOS	2b
E	OpenEhr	4a

Generic Level		A 3a	B 2a	C 3c	D 2b	E 4a
A	3a	3a				
B	2a	2a	2a			
C	3c	3a	1a	3c		
D	2b	2b	2b	3a	2b	
E	4a	3a	2a	3c	1b	4a

Specific Greater than expected	S > E	(blue)
Specific Equal than expected	S = E	(green)
Specific Less than expected	S < E	(yellow)

Fig. 3. Specific versus expected level assessment matrix

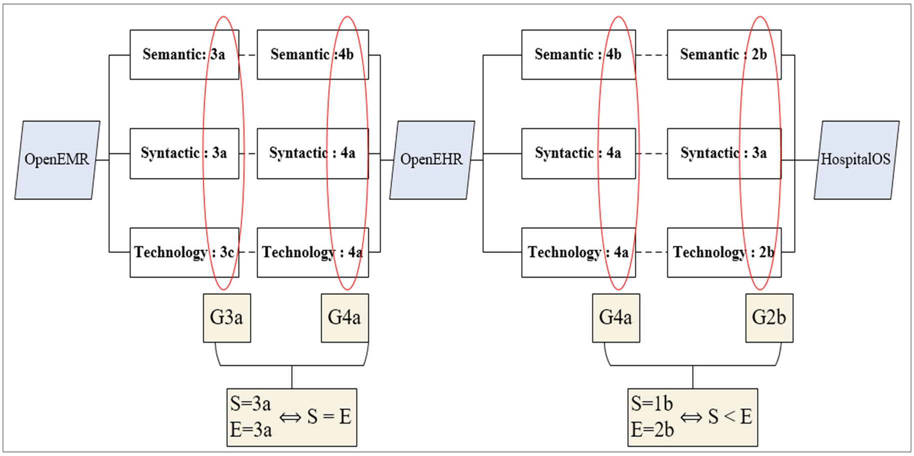

Fig. 4. Evaluation of interoperability level based on (SST)

The results revealed form the evaluation matrix that, while some Ehrs can communicate in synchronization without barriers (OpenEmr to OpenEhr), others have limited capacities with respect to the SST modules.

In fact, if we take for instance OpenEHR and HospitalOS, we note the existence of major gaps (see Fig. 4). This is mainly due to the HospitalOS profiling system, which has lower capabilities in regards to the SST metrics. Hence, in order to improve their exchange, it is necessary to integrate the needed health modules starting from the connected level, as it is the high level of sophistication that HospitalOS has achieved.

On the contrary, OpenEHR to OpenEmr link indicates that an exchange of data can be performed without problems, since the specific and the expected level are equivalent. In fact, OpenEHR has a widely developed platform and represents a reference model that allows an easy integration of different health terminologies and ontologies. In this sense, the two Ehrs will operate and share data according to the lowest level which corresponds to the OpenEmr system profile.

As a summary, the Ehr systems can exchange data at the basis of their system profile, which may either meet the requirements of the SST attributes or need to upgrade their capabilities starting from their achieved level.

6 Conclusion

In this paper, we presented an evaluation methodology based on LISI interoperability model, through which we proposed a novel prototype for application to the health sector. This was assessed by the integration of the semantic, syntactic and technology (SST) modules. The implementation process allowed the evaluation of some existing electronic health records along with a successful measurement of the interoperability level. At last, an assessment matrix was generated to illustrate the ability of two systems to exchange health data.

This study will push researchers to focus more on improving interoperability solutions, rather than conceiving new Ehr softwares with novel distinct technologies. A major perspective of this prototype is the conception of a linear regression model based on the correlation between the (SST) modules, in order to measure precisely the metrics of each defined parameter.

References

1. Aso, S., et al.: Analyzing SNOMED CT and HL7 terminology binding for semantic interoperability on post-genomic clinical trials. Stud. Health Technol. Inform. **192**, 980 (2013)
2. Bhartiya, S., Mehrotra, D., Girdhar, A.: Issues in achieving complete interoperability while sharing electronic health records. Procedia Comput. Sci. **78**, 192–198 (2016)
3. Ed Hammond, W.: Standards for global health information systems. In: Global Health Informatics, pp. 94–108. Elsevier (2017)
4. C4ISR Architecture Working Group: Levels of Information Systems Interoperability (LISI) (1998)
5. Iroju, O., et al.: Interoperability in healthcare: benefits, challenges and resolutions. Int. J. Innov. Appl. Stud. **3**(1), 262–270 (2013)
6. Jaulent, M.-C., et al.: Semantic interoperability challenges to process large amount of data perspectives in forensic and legal medicine. J. Forensic Leg. Med. (2016)
7. Noumeir, R.: Requirements for interoperability in healthcare information systems. J. Healthc. Eng. **3**(2), 323–346 (2012)
8. Rezaei, R., Chiew, T.-k., Lee, S.-p.: A review of interoperability assessment models. J. Zhejiang Univ. Sci. C **14**(9), 663–681 (2013)
9. Ruggaber, R.: ATHENA - Advanced technologies for interoperability of heterogeneous enterprise networks and their applications. In: Konstantas, D., et al. (eds.) Interoperability of Enterprise Software and Applications, vol. 1, pp. 459–460. Springer, London (2006)
10. Sachdeva, S., Bhalla, S.: Semantic interoperability in standardized electronic health record databases. J. Data Inf. Qual. **3**(1), 1–37 (2012)

11. Synitech. openemr/openemr. GitHub. https://github.com/openemr/openemr. Accessed 28 Mar 2017
12. Wang, W., Tolk, A., Wang, W.: The levels of conceptual interoperability model: applying systems engineering principles to M&S. arXiv:0908.0191 [cs] (2009)
13. Zaidan, A.A., et al.: Multi-criteria analysis for OS-EMR software selection problem: a comparative study. Decis. Support Syst. **78**, 15–27 (2015)