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Interoperability Assessment Approach in Cancer Healthcare

Victor SCUISSIATTO[1], Eduardo LOURES[2] and Eduardo PORTELA[3]
Pontifical Catholic University of Paraná

Abstract. Hospitals have constantly pursued quick, efficient, and quality services in order to fulfill customer/patient needs, thus causing improvement and innovation capability to be in tune with the processes executed. In general terms, services have been a big challenge to hospitals, once the current demand is not fulfilled. The appropriate management of processes and information flow greatly influence the operational performance of the involved hospital entities. Such integration and collaboration scenario promotes the identification of barriers to the organizational good performance, and regards interoperability perspectives an important assessment tool. This paper presents the IAMinCH - Interoperability Assessment Model for Cancer Healthcare domain, designed for the assessment of the interoperability capability in the cancer treatment sector, which is complex a analysis structure based on the AHP method, performance attributes deriving from different information sources are assessed and organized under the interoperability perspective. The results achieved enable a diagnostic view that better addresses the development of an improvement plan concerning the hospital interoperability capabilities in cancer healthcare.

Keywords. Interoperability. Process. Evaluation. Health Care.

Introduction

Currently, hospitals have faced a social and economic period characterized by higher demand and an increasing need for more and better communication, interaction, integration, and cooperation [1]. The healthcare continuous improvement, regarding information accessibility and efficient processes during hospitalization, requires a better information management as well as the cooperation among the parts involved in the healthcare process [2]. In this way, interoperability and its assessment has been employed as a tool for communication and process improvement and optimization in the healthcare area [3]. Literature brings several methods related to interoperability assessment [5]. Such methods cover different issues, contexts, and domains by means of different approaches. Many research papers [9][10][11] and initiatives have been proposed in order to identify interoperability dimensions and define a knowledge structured framework in the healthcare domain, e.g. Nehta, eHealth FEI – Framework Interoperability, Personal Health System - PHS [7][8][13]. But, a common however understanding and a consensus about such dimensions is still open nevertheless. This paper targets applying process mining through organizational mining in the healthcare

[1] Victor Ricardo Scuissiatto. [victorscuissiatto@me.com]
[2] Eduardo de Freitas Rocha Loures. [eduardo.loures@pucpr.br]
[3] Eduardo Alves Portela Santos. [eduardo.portela@pucpr.br]

processes in order to obtain knowledge on organizational flows, organizational structures and social network analysis among the organizational entities. In this paper, we describe process mining and organizational mining in section 1, section 2 provides a description of the mothodology proposed by this research, section 3 contains the case study applied at Erasto Gaertner Hospital and section 4 brings the conclusions.

1. Interoperability in Healthcare

Among the various definitions of interoperability, the most commonly employed is "the ability of two or more systems or components to exchange and make use of the information exchanged" [11]. In healthcare systems, interoperability is a key requisite to ensure service quality in a fast and efficient way. Healthcare demands hospital services characterized [13] by an appropriate coordination of processes and efficient information exchange among different systems. In such environment [3][5], people involved must fully understand these perspectives (information and processes), requiring an adequate organizational structure that includes technology and management perspectives in order to minimize the barriers to the good organizational performance, and aiming to optimize the interoperability capability [9][10]. Among the different interoperability models and frameworks found in literature, some are specifically related to healthcare [10]. The objective consists in providing an organization mechanism so that interoperability concepts and perspectives in a hospital environment are better structured and represented. Some of these frameworks are presented in a comparative chart, which will be the foundation to the knowledge organization and structural requisites for the conception of an interoperability assessment model. The first one belongs to the wider interoperability context, and are mentioned given their relevance in the present research context.

Developed on the INTEROP application – European Excellence Network [18], the **Framework for Enterprise Interoperability (FEI)** classifies and defines three interoperability dimensions: barriers, concerns, and approaches [4][5]. According to the FEI, the *interoperability barriers* refer to the removal of obstacles identified for the establishment of interoperability. Three types of barriers are identified: (i) *conceptual* – related to syntactic and semantic differences of information to be exchanged; (ii) *technological* – regarding the incompatibility of information technologies; and (iii) *organizational* – related to the organizational and management structure employed by enterprises. *Interoperability concerns* refer to the diagnosis or establishment of interoperability at different operational levels. (i) *data* interoperability; (ii) *service* interoperability – concerning the identification, composition, and execution of several applications/services (independently conceived and implemented); (iii) *process* interoperability – regarding the coordination of processes; and (iv) *business* interoperability – referring to the organizational structure, models, and business rules.

The **E-Health Interoperability Framework** [13] was developed by the National E-Health Transition Authority (NEHTA), Australia. It illustrates the definition of three interoperability perspectives oriented to healthcare organizations – organizational, informational, and technical. The *organizational* perspective comprehends the shared information policy and process structure aspects as well as business rules. This perspective includes business, security policies, and privacy. The *informational* perspective regards shared structures of semantic creation based on

information interchange [13]. The *technical* perspective refers to the connectivity of data exchange systems and the use of services. The **Health Information Systems Interoperability framework (HIS)** [19] is a reference framework created by the ASIP Santé (Agence Nationale des Systèmes d'Information Partagés de Santé) [19] aiming to promote the development of services for the electronic exchange of personal healthcare information and for the creation of interoperability conditions among HIS systems that meet privacy and security requisites. This reference framework specifies the standards to be employed in the exchange of personal healthcare information via systems. In addition, the model depicts the execution procedure of these standards so as to enable the development of interoperability among HIS systems in accordance with the privacy and security requisites [19]. This **Personal Health System (PHS)** [20] reference consists in supporting the supply of continuous quality control services as well as the supply of customized services, regardless the location of the person [20]. The PHS Interoperability Framework (PHS IF can be included in two minor structures: (i) technical and execution structure, including rules, profiles, and directions with regard to its implementation based on the usage background of the designed business, identification, and authentication tools, security protocols, essays and certification; (ii) an organizational chart and political issues, governance, legal aspects and regulations, such as data protection and responsibility. Table 1 shows the comparison between the frameworks presented. The assessment is founded on the interoperability dimensions defined by the FEI, which points out its extensibility to the hospital domain in the assessment of organizational and business perspectives [4]. The use of such structure as assessment base for different application domains is corroborated by literature, such as in [2] [9] [21] [22] [23]. In the construction literature there is no model that considers three different informational sources in the multi-criteria evaluation model evaluation capability for interoperability, thus evidenced the comparative models for applicability in Hospital Domain.

Table 1. Comparative Interoperability Overview.

	EIF	Ehealth	HIS	PHS
	Overview			
Interoperability dimensions	*Organizational *Technical *Semantic	*Legal *Organizational *Technical	*Semantic *Technical	*Organizational *Technical
	Interoperability Barriers			
Technological	●	●	●	●
Conceptual	●	◐	●	○
Organizational	●	◐		●
	Interoperability Concerns			
Business	◐	●		◐
Process	●	●	◐	●
Service	◐	○	●	●
Data	●	◐	●	◐

Assessment makes use of the following notations:
● High concern - model criteria fulfillment.
◐ Medium concern - partial fulfillment of criteria
○ Low concern - minimal fulfillment of criteria
' ' No concern – no fulfillment or approach to the criteria

2. Interoperability Assessment Model For Cancer Healthcare Domain - IAMinCH

The interoperability improvement implies in the need to define assessment metrics. Measuring or assessing interoperability allows the identification of weaknesses and strengths faced by enterprises or hospitals in order to interoperate, and thus prioritize improvement actions [10]. In literature [15], it is possible to find a number interoperability assessment models and methodologies, comprising both quantitative and qualitative approaches under the different perspectives pointed out by the different Interoperability Frameworks (IF) and considering the organization's temporal and

contextual positioning.The comparative chart (Table 1) highlights the adaptation of the FEI and EIF frameworks to the healthcare domain, corroborated by the authors in [9], who state that both IFs constitute a general framework for business interoperability and it can be applied to a healthcare enterprise. According to Chen [4][5], the interoperability diagnosis or establishment consists of the identification of different operational levels of an enterprise, therefore allowing the conceptual adaptation to a hospital based on the perspectives and barriers identified in the presented frameworks.

Through the views representation [3] associated with the barriers (conceptual, technological, and organizational), the model becomes complete and may represent the hospital structure, detailing perspectives such as: business, process management, policies and procedures, HR, IT, and semantics. Regarding this conceptual structure, the development of an assessment model strategy is proposed, the IAMinCH – Interoperability Assessment Model for Cancer Healthcare domain. Such strategy is shown in Figure 1, illustrating the path followed and the strategy for the interoperability measurement final objective suported by the IAMinCH. The hospital is presented as the application domain, focusing on the declared processes of the oncology sector.

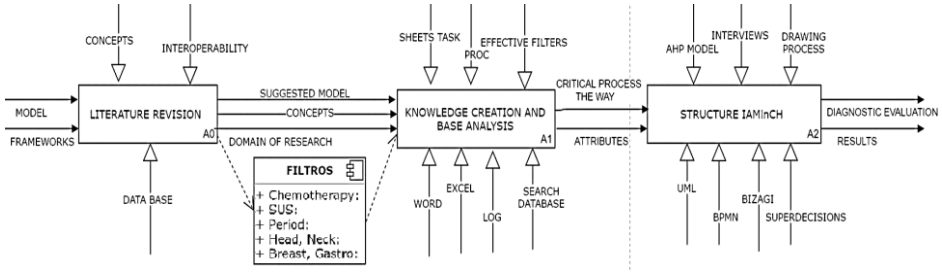

Figure 1. IAMinCH development framework.

Steps from A0 to A2 (Figure 1) based on the IDEF0 notation [6], illustrate the knowledge development and organization inherent to the hospital context, so as to reveal and raise the interoperability domain attributes related to the oncology process, and provide structural subsides to the IAMinCH construction. Step A0 regards the literature review, considering models and frameworks related to interoperability as input and the model proposed with the identification and filter of the domain to be used as output. The "Filters" component (from component A0 to A1) represents a scope delimitation regarding the oncology processes. In this way, they are considered as the most critical (known as "lifeline") and relevant in the performance assessment and interoperability requisites. The amount of information shared within the processes is above one thousand and the number of possible routes in the hospital processes flow is very high. In this way, the lifeline of the cancer treatment process is obtained, delimiting to Chemotherapy and the instances indicated by the 'Filters' component in Figure 4 (SUS - Unified Health System, head/neck, breast/gastric). The A1 component is responsible for the knowledge organization and the analysis base formation based on the information sources: task sheets (specialist declared description of the executed processes), PROCs (institutional normative reference), and execution registers of the management systems (logs). The awareness of the critical path and qualification attributes of the assessment domain supports step A2 in the structural development and assessment model usage based on the AHP (Analytic Hierarchic Process) multi-criteria

assessment method, the IAMinCH. As a result, a diagnostic assessment of the attributes capability and interoperability levels related to the oncology processes at the hospital is obtained. A more detailed analysis of steps A1 and A2 in the framework (Figure 1) is presented next.

2.1. Step A1 - Analysis base and atributes

The data surveying step of relevant information to the operational performance assessment, under the interoperability perspective, is characterized by the need to identify qualifying attributes. In the scope of this paper, attribute refers to what is inherent to something, such as characteristics, classes, and variables that allow the organization to make remarks and be able to assess and achieve interoperability in the hospital context. Guidelines refer to the attribute through business rules established by the hospital model. Three stages for the surveying of attributes and guidelines were carried out culminating in the IAMinCH structural specification. In the **First Stage** filters were defined, given the complexity and size of a hospital with regard to the amount of information shared within its processes. Inspired by Chalmeta [3] and Espadinha [24], such filters refer to an identification process for critical paths, which considers the amount of information and intra-sectorial coordination of processes through a matrix and relational inference. As a result, filters defined-leading processes related to Oncology reception sector: (i) new patients; (ii) SUS referred (Unified Health System); (iii) under cancer suspicion; (iv) breast, head, neck, and gastric; the 30-day period was considered. Based on the scope resulting from the filters applied in the first stage, information surveying characterizes the **Second Stage**. As previously highlighted, the focal perspective of hospital processes led us to a triple information source deriving from this perspective. They are: (i) PROCs – internal procedures of the hospital, conceived under the light of international recommendations for cancer treatment; (ii) TSs – Task Sheets, register and assessment artifact of the processes executed and declared by the involved parts; and (iii) LOG registers generated by the hospital management and information system.

The **Hospital Internal Procedures (PROCs)** This document stores the procedures that must be executed by sectors and departments during the hospital work shift. This description of procedures is characterized by steps, each interaction of the responsible by the process, what interactions are executed, and who executed them (responsible by the execution). Such reference permits the identification of interaction between processes and sectors, systems, and people. The associated information flow interacts along the process path with sectors; such interactions can be electronic and physical information exchange (patient prompt, healthcare card), procedures (stamp, signature). Therefore, the PROCs represent procedural reference models, providing a number of attributfes and information forwarded or exchanged with sectors involved in the process. The **Task Sheets (TSs)** are artifacts developed in order to collect information about the process flow, making use of interviews (process declared knowledge). In the present paper, the purpose of the TS consists in providing the foundation to analysis of attributes, through the assessment of the process executed (declared) in accordance with those described in the PROCs. The fields in the TS corroborate with the data survey registered in the PROCs, in addition to fields to register the possible interactions with departments and among systemic processes, either dependent from the information system or not. não. Thus, assessment attributes are identified, and their fulfillment during the process flow is checked, being the base for measuring the interoperability level. In this way, making it possible to evaluate the fulfillment

potential of the attributes identified by the sector in the internal procedures (PROCs). The task sheet must be approved by the professionals involved in the process, thus providing the tool with an approval from the declared process. The hospital associated with the development of this paper employs an information and management system called Tasy. The system main focus resides in fulfilling and managing information so that the patient is easily admitted and identified within the hospital environment. In the system database, the patient information and prompt are stored for internal and, sometimes, external access. These data are stored during the patient admission process and are used in all sectors and departments, demonstrating the inherent complexity present in the fulfillment of interoperability requisites.

The Third Stage consists in analyzing and conciliating information derived from previous stages (information sources) as well as organizing knowledge obtained from the attribute definition base. The organization structure obtained from these attributes must be supported by the IAMinCH assessment method, permitting the issuing of a diagnosis of the existing interoperability level with regard to the critical path related to oncology processes. In order to support this modeling process of the assessment knowledge, a relational matrix inspired in the IACM model (Interoperability Attributes Correlation Matrix) [25] is proposed in. The matrix indicated in Figure 2 focuses on the correlation analysis of the involved domain attributes with the interoperability perspectives (Business, Process, Service, Data). The positioning of the attributes in the interoperability quadrants permits the categorization required for the assessment organizational structuring adopted by the AHP method. The relational matrix was generated with the attributes found in the TSs and considered as the most important ones. Additionally, the importance of each attribute was assessed according to the *interoperability concerns* referring to the interoperability diagnosis or the establishment inspired by the Frameworks under study. In such assessment only Business, Process, Service, and Data were considered, once these views are merged in the Oncology sector. As an example of assessment, the attribute "*Request/APAC Search*" is described as a budget request to the Unified Health System (SUS), thus placing more importance on the Business aspect. It means that if the APAC is not appropriately executed, it may have a relevant impact on the Business aspect.

	Communication SUS	Solicitation APAC	Register	Schedules	Records in Evolution - PEP	Consultation and Screening	Exams	Infusion Chemotherapy	Communication hospital patient	Process Registration - PROCS	Medication administration	Guidelines patient	intersectoral communication	Release Status APAC	Administrative Supervision		Importance (%)
Business	9	9	1	3	1	1	3	1	9	9	3	3	9	9	9		25
Process	3	3	9	9	3	9	3	9	3	9	9	3	3	1	9		25
Service	3	3	3	3	3	9	9	9	9	9	3	9	3	1	3		25
Data	9	1	9	9	9	3	9	3	9	9	3	9	9	9	9		25
Degree of importance (Req. Product)	600	400	550	600	400	550	600	550	750	750	450	600	600	500	750	8650	100
Percentage	6,94	4,62	6,36	6,94	4,62	6,36	6,94	6,36	8,67	8,67	5,20	6,94	6,94	5,78	8,67	100	

Figure 2. Matrix relational HealthCare.

2.2. Step A2 - IAMinCH Structure

The IAMinCH structure (Interoperability Assessment Model in Cancer Healthcare) was developed as an assessment model for interoperability in the healthcare domain. This structure assesses the attributes established by arranging them according to the AHP -

Analytical Hierarchy Process method. Given to subjective or intuitive considerations that suggest the relational assessment of different criteria (attributes), the AHP is particularly appropriate to the healthcare specific scenario and the assessment of the existing interoperability potential in the considered domain. The employment of the AHP begins with the problem breakdown within a hierarchy of criteria (categories) that are more easily and independently compared. After creating such criteria, the decision makers comparatively evaluate the alternatives, considering each of the criteria, i.e., fulfilled, partially fulfilled, and not fulfilled. This assessment determines the alternative probability to meet the established target. The higher the probability, the more expressively it contributes to the final objective (interoperability level). Figure 3 illustrates the structure AHP for evaluation problem modeling, consisting of 4 levels. The first (EIA - Enterprise Interoperability Assessment) refers to the goal of assessment of potential interoperability in the hospital sector oncology; the second (Criteria) considered the criteria represented by the prospects (concerns and aspects) interoperability (Business, Process, Service, Data); the third (Attributes) represent the attributes organized in quadrants (Figure 2); the fower level (Level / Maturity) identifies the potential for interoperability of Oncology through the maturity level diagnosis.

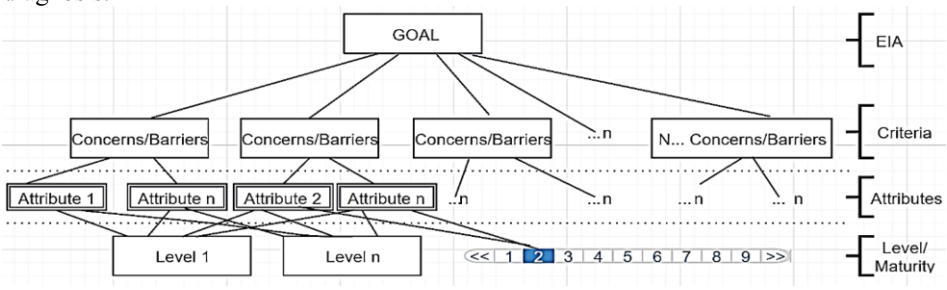

Figure 3. AHP Structure of the IAMinCH.

3. Application Case

The IAMinCH was carried out application in a hospital located in Curitiba – Brazil having as mission "fighting against cancer with humanism, science, and care". The hospital is a reference in cancer prevention, diagnosis, treatment, and research in southern Brazil. An average of 1366 patients are admitted at the hospital every day, most of them in the Oncology. By using Task Sheets and PROCs it was possible to identify the assessment attributes and their structuring and organization through the relational matrix (Figure 2). The identification of the process critical path enables the definition of the involved sectors and, therefore, determine the interoperation potential assessment domain of the involved entities. Stages and components described in Figures 4 and 5 lead to IAMinCH development in Super Decisions Platform for diagnosis. The are presented as follows.

Based on the Task Sheets and PROCs, attributes indicated in Table 2 were obtained the raised attributes in order to measure compliance, Figure 4 ilustrates the information flow between the process actors highlighting the related attributes. The task sheet selected was sheet number 05. This task sheet describes the activities in the Nursing sector. The goal of this sector consists in advising the patient with regard to

the treatment on course, providing information such as side effects, duration of chemotherapy sessions, intervals, and cycles. This sector become crucial for the establishment of attributes and due to the amount of associated information and relations. PROC was selected as support to the knowledge base construction for interoperability assessment.

Table 2. List of extracted attributes.

	IN	FOR	INFORMATION
A1 RECORDS	NURSE	TASY	RECORDS ON LINE
A2 CUSTOMER INF	NURSE	PATIENT	CHECK LIST QUIMIO
A3 LEADING	PATIENT	PAPEL FÍSICO	LEADING
A4 AFFIRMATION	PATIENT	CLINICAL	RECEIVED VIA SIGNED GUIDANCE
A5 EVOLUTION	NURSE	RECORDS	STORING DOCUMENT SIGNED
A6 RULE APAC	NURSE	E-health	APAC APPROVAL OF CONSULTATION
A7 SCHEDULING	NURSE	TASY	SCHEDULING CHEMOTHERAPY
A8 TEST	NURSE	TASY	CHECKS EXAMINATION

Based on the relational matriz in Figure 2 and the AHP hierarchical structure indicated in Figure 3, the IAMinCH structure is executed on the Super Decisions platform. The decision makers comparatively evaluate the alternatives according to each of the criteria. The hierarchy structural defines through a pertinence assessment of each attribute, its interoperability quadrant. By applying the methodology, it is possible to determine the importance of each Criterion/Concern on each alternative (fulfillment level). Also, the importance of each criterion and attribute on the overall objective is verified, which consists in determining the potential level of interoperability of defined heath care.

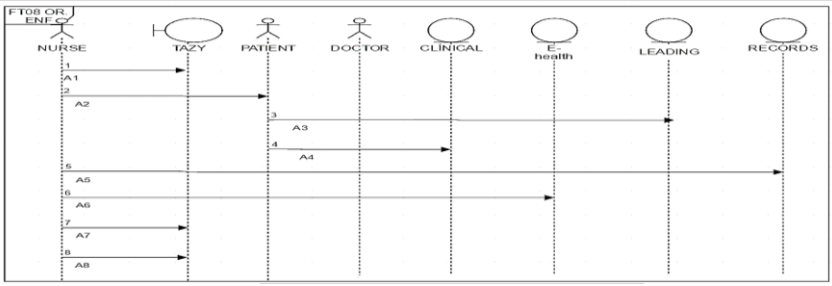

Figure 4. Process Path and Establishment of Attributes.

Table 3 shows that most attributes present partial partial capabilities in the Oncology sector with regard to the hospital. This means an interoperability level remained at level 2, as in Figure 4. From this diagnosis view, interoperability barriers could be identified and an improvement plan carried out by the Hospital.

Table 3. Effective/Potential Interoperability Analysis.

	Interoperability Concerns				Interoperability Approaches		
Atributes	Business	Process	Service	Data	Attended	Partial	Not Attended
A1 RECORDS	x		xx	xx	x		
A2 CUSTOMER INF	xx					x	
A3 LEADING	x	xx	x			x	
A4 AFFIRMATION	x	x	x			x	
A5 EVOLUTION			x	x		x	
A6 RULE APAC	x						x
A7 SCHEDULING	x	x	x			x	
A8 TEST							x

Name	Graphic	Ideals	Normals	Raw
NÍVEL 1		0.695349	0.274221	0.274221
NÍVEL 2		1.000000	0.394365	0.394365
NÍVEL 3		0.840376	0.331415	0.331415

Figure 5. Potential/Result Interoperability.

4. Final Considerations

Hospitals have faced a higher demand than their overall service capability, evincing their increasing need to improve communication, interaction, cooperation, and processes. The hospital organizational performance finds in the interoperability perspectives an important assessment tool. This paper focused on the oncology sector due to its complexity and importance to the hospital. In this way, a diagnostic assessment of the attributes capability levels as well as the hospital interoperability level related to oncology processes have an applicable value. The use of the proposed IAMinCH assessment method allowed the diagnosis of the interoperability level existing in the critical path sphere regarding oncology processes employing the data collection stages, the existing policies, and information systems. The AHP allows the problem space structuring with regard to task sheets (TSs) and PROCs, thus identifying the progress of attributes in relation to the potential interoperability. After the execution of the IAMinCH, it was identified that the interoperability potential in the oncology sector is being partially fulfilled. The proposed framework and its developing cycle, supporting a knowledge identification and its modeling through a decision analysis method (AHP) brought adequate interoperability assessment requirements in Health Care, dealing with imprecise, qualitative and tacit knowledge.

In future work, the application of new MCDA methods (multi-criteria decision analysis) to new cases in the healthcare field will be investigated. More specifically, the Electre TRI method will be highlighted, given that it allows a more refined assessment definition of each criterion, and thus the consideration of quantitative intervals – appropriate to the use of metrics stemming from registers of the hospital management systems through the employment of processes mining.

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