A framework for next generation e-health systems and services

Full Paper

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Abstract

We propose a framework for the development of next generation e-health systems and services. It results from the joint work of diverse research groups with 20 to 25 years of experience in their respective fields (e.g., business process management, medical informatics, business intelligence), and it articulates five elements: the mining of care workflows; their compliance with medical guidelines; their execution in a specialized engine capable of dealing with the inherent variability that exists in healthcare processes; the use of business intelligence techniques; and the integration with communities of practice that are key for the evolution of socio-technical systems. For each area, we describe its context and objectives, the state-of-the-art and challenges, leading up to the proposed innovation and its implications. The framework demonstrates how multidisciplinary research can enable a reinforcement of leadership in healthcare by supporting novel medical care with more predictive, individualized, effective, and safer solutions.

Keywords

Careflows, careflow compliance, careflow management system, process mining, healthcare intelligence.

Introduction

Rising healthcare costs have become an issue in many countries. Understanding the role and impact of careflows (sequences of healthcare activities) can help institutions in reducing expenditures, increase efficiency and quality of patient care. We present a careflow-based framework that proposes advances for the next generation of e-health systems and services. It brings together key disciplines around five process-centered areas: discovery, compliance, execution, monitoring and analysis, and collaboration to enable the development of process-aware end-to-end systems (Dumas et al., 2005).

The goal of discovery is to ascertain actual healthcare processes by extracting knowledge from event logs (i.e., hospital information systems, medical equipment, and patient information). Our framework proposes to use careflow mining (van der Aalst1, 2009; van der Aalst2, 2009) to identify, from evidences of normal operation, how care processes are de facto performed. For instance, patients receiving medical assistance leave traces of information that can be used to reconstitute the careflows that the patients were subject to in a bottom-up manner, providing a more realist picture of how the organization operates than a traditional top-down modeling could. Once discovered, we move on to ensure that careflows meet the requirements of healthcare guidelines (GL), protocols, procedural manuals, code of practice, and laws. Research has shown that information systems are an effective way to increase the compliance of treatments (Kawamoto, 2005; Purcell, 2005; Albert, 2007). Once evaluated as compliant, careflows serve as blueprints to manage patients' treatments by using a flexible CareFlow Management Systems (CfMS), since traditional business process management systems (BPMS) are too strict to deal with the inherent variability that exists in healthcare processes. During the execution of careflows, Healthcare Business Intelligence provides methods and applications for gathering, storing, analyzing, and access to careflow data to help a better decision-making process. So far, little research has been directed towards analysis and monitoring of processes (Grigori et al, 2004, Deutch, 2008, Beeri et al, 2007). Horizontal to all these four key areas, collaboration platforms with professional social networks and social communities of practice support sharing, commenting and managing of careflows. This type of communities is an important catalyst of social processes (de Moor, 2005) and is driving the evolution of socio-technical systems (Wenger et al., 2002).

The remainder of this paper is organized as follows. In section 2, we present the proposed framework and discuss its five core areas, guiding the reader from introduction to implications in each. Section 3 describes our research methodology just before our conclusion in section 4.

A framework for next generation e-health systems and services

In Figure 1 we illustrate how the five scientific and technological areas underlying the proposed framework for e-health systems and services come together.

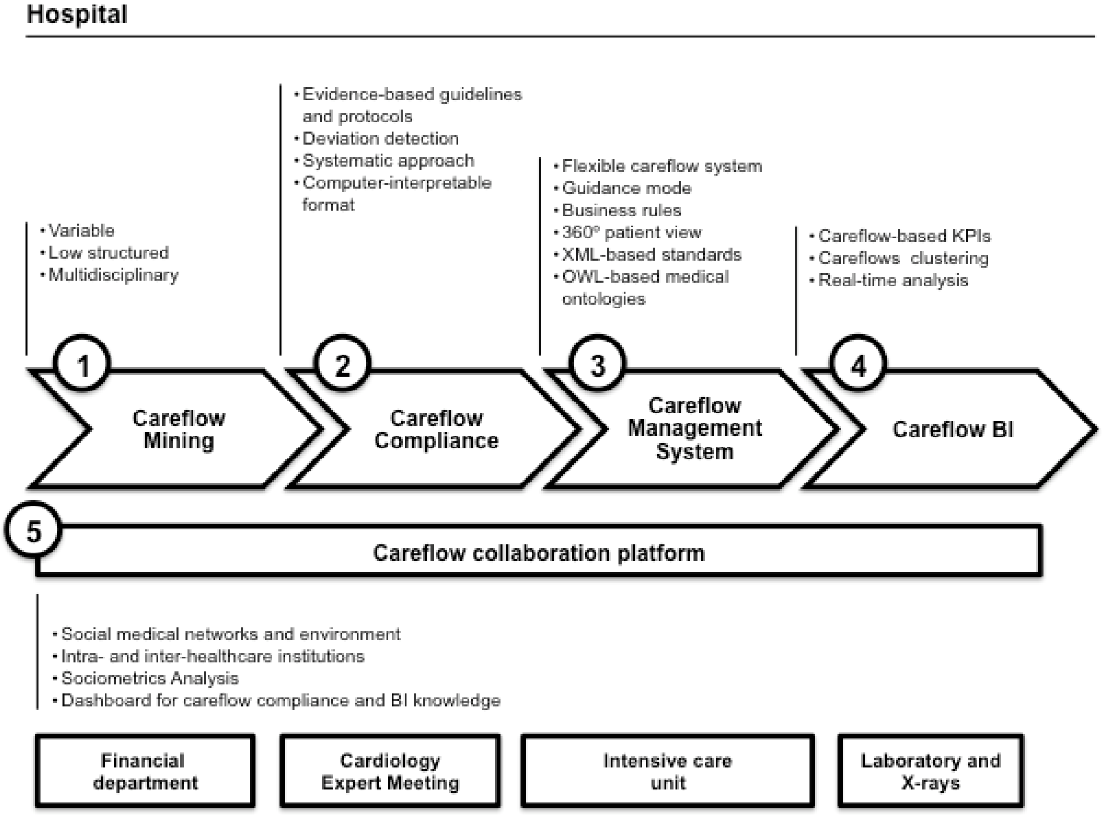

Figure 1. Framework for next generation e-health systems and services

Careflow mining (1) is concerned with new techniques and algorithms to identify the de facto care workflows that are in place at the hospital (van der Aalst, 2009). Instead of relying on business analysts to manually identify, graphically design, and document those processes – a costly and time consuming procedure – our approach automatically discovers these high-level workflows by reverse engineering them from traces that everyday operation leaves in the various hospital systems, such as calendars, lab equipment, and billing systems. After the discovery process, the resulting workflows are analyzed for compliance (Panzarasa, 2007) with clinical practice guidelines, protocols, and best practices stated in national and international laws and regulations (2). Doctors and hospital administrators can manually adjust the careflows to eliminate non-compliances, after which they are deployed to the CareFlow Management System (CfMS), a specialized Business Process Management System (Cardoso and van der Aalst, 2009) for healthcare environments (3). This engine implements a flexible execution, called guiding mode, which allows for deviations from standard procedure when justified. Nevertheless, for quality assurance and adherence to regulations, a rule engine detects any non-compliant behavior. Being the blueprints for all patient-related processing, careflows provide a 360º view on them, by integrating all disparate healthcare data that is usually spread out across various systems. Business Intelligence (Grigori et al, 2004) comes next (4), as key performance indicators (KPIs) are collected in real-time from the careflows. Data on compliance violations, on the quality of lab tests, on missing information in records, among others, enables decision-makers to take grounded decisions about process tuning. Finally, a collaborative platform (5) brings together healthcare professionals so that they can contribute with their knowledge. Collective intelligence is leveraged using professional social networks to focus on particular aspects of social processes (de Moor, 2005) and support socio-technical systems (Wenger et al., 2002).

In the following sections, each of these key areas is analyzed in detail. For each, we introduce the context and objectives, followed by challenges, state-of-the-art, and proposed innovations and its implications.

Careflow Mining

Context and objectives

Typically, people involved in careflows only have a limited or idealized view of how these processes are executed. That is, they tend to have an ideal scenario in mind, which, in reality, is only one of the many possible unfoldings of the workflow. On the other hand, manually designing careflows is too costly and time consuming. Process mining is of great value in this context, as it aims at extracting process-related information from event logs created by existing hospital systems that record information about careflows that have been executed. Since the availability of medical personnel is typically limited and scarce, it is important that the obtained process insights can be quickly communicated to the medical personnel and, thus, contribute to enable a better decision-making for hospital administrators.

This reality leads to the following two objectives. First, since a wide variety of systems that record careflow information can be found in healthcare institutions, in order to obtain useful and trustworthy event logs it is essential to develop a classification of systems providing guidance into the identification and integration of different sources of data, and the inherent problems that are related to it. Second, since careflows are known to be highly variable, poorly structured, and cross multiple medical disciplines, it is necessary to develop new mining techniques which effectively describe the careflow under consideration, showing the ordering of activities, and the actors of the medical disciplines that are involved.

State-of-the-art and challenges

Almost all mining algorithms present a discovered careflow as a procedural/imperative model. Procedural languages are suitable for repetitive processes with tight control but fail in representing flexible processes (Chesani et al., 2009). Consequently, mining results obtained from flexible careflows are unstructured and hard to understand. Conversely, declarative process languages describe a process by means of constraints: any execution that does not violate constraints is possible, which makes them a better fit for flexible careflows (van der Aalst and Günther, 2009; Pesic and van der Aalst, 2006). So far little research has been done on the discovery of declarative models. Current approaches heavily rely on the availability of negative information, i.e. behavior will never occur or is forbidden to occur (Chesani et al., 2009; Ferreira and Ferreira, 2006; Goedertier, 2008; Cataffi et al., 2010). However, event logs do not record what cannot happen, but rather what did. Additionally, the quality of process models leaves much to be desired (van der Aalst1, 2009, van der Aalst2, 2009). For example, models are not tailored towards a specific purpose. Also, they tend to show irrelevant details and do not show that some activities or process paths are more important than others (Günther and van der Aalst, 2007, van der Aalst1, 2009, van der Aalst2, 2009).

Providing the needed classification for the heterogeneous systems in a healthcare institution and the guidance on how to obtain process related information in an effective way is far from trivial. Additionally, current process mining techniques have problems dealing with the flexible nature of careflows. So, the challenge is to develop mining techniques that are able to capture the variability and low structure that exists within careflows. Moreover, the obtained mining results need to be communicated in a quick and convincing way.

Innovation and Implications

It is clear that the mining of declarative models is still in its infancy. So, the development of new less procedural techniques is necessary. Declarative models are based on constraints that mean that negative information needs to be available. Advanced techniques need to be developed in which this negative information can be discovered based on historical data or can be inferred in another way. For the visualization of careflows the current situation must be dramatically improved, by devoting it specific attention. Here, we can learn from geographical information systems and the way a car navigation systems present different types of information (zoom-in/zoom-out, see traffic jams, speed limits etc.). Additionally, work done in the field of visual analytics needs to be considered. Visual analytics aims at presenting huge amounts of information in an understandable and interactive way (Mansmann et al., 2006; van Ham et al., 2008; Volz et al, 2013).

Implication 1. More predictive, individualised, effective and safer healthcare.

Careflow Compliance

Context and objectives

Non-compliance detection may have different meanings. First, analyzing the careflows automatically identified by process mining allows discovering systematic differences between expected and real processes: if any, discussion with medical and administrative experts will help designing a CfMS to be enacted within healthcare organizations, facilitating professionals to comply with best practices. During the very first enactment phase, non-compliance detection is useful for the system validation (i.e. the user can be non-compliant simply because the system provided a bad suggestion, due to a model error). Once the model flaws have been fixed, and the final CfMS delivered, non-compliance must still be detected: it helps find human errors, lack of resources, or disagreement with the suggestions (probably due to patients' peculiarity). After some time, interestingly, non-compliance could also indicate a practice is becoming obsolete because of new scientific evidence, but the careflow model has not acknowledged this change yet.

The main objective in careflow compliance is to develop a closed loop system that allows exploiting quantitative measures of users' compliance to improve the quality of the delivered care. More precisely, the loop to close is the life cycle of guidelines and protocols: currently, these documents are updated only on the basis of new scientific evidence, but users' feedback is also of paramount importance. Thus, we propose the development of a technological support for detecting, analyzing and discussing non compliances, addressing two target users and goals: the careflow users, that more easily will adhere to best practice, and the guideline/protocol developers, that more quickly will be alerted of any flaw in careflow logic. These objectives may be achieved by classifying non-compliances according to multiple axes: a) their severity, that can be measured through the level of scientific evidence supporting the recommendation, and b) their causes/motivations, taking into account that a non compliance does not necessarily imply a malpractice.

State-of-the-art and challenges

Despite the great confidence in the potential of evidence-based medicine, compliance with guidelines (GLs) was and continues to be poor (Cabana, 1999; Eccles, 2002; Leape, 2003; Barner, 2003; Jami, 2007). Several studies show that computerized decision support systems improve clinicians' compliance (Kawamoto, 2005; Purcell, 2005; Albert, 2007), particularly if they are fully integrated with the work processes of clinicians (Sim, 2001). Moreover, it is agreed that documenting clinical activities is of paramount importance, particularly when a clinician practices outside the guidelines (Pelly, 1998). Different approaches exist for compliance checking, from computational logic-based frameworks as GPROVE (Chesani, 2008) to minimally intrusive critiquing systems, giving advice when the user's decision is out of the system's permissible range (van Bemmel, 1997; Panzarasa , 2007). Investigating the causes of non-compliance is important from the medical practice point of view, see Gilligan (2007) describing an American study on the compliance with breast cancer guidelines, and Maviglia (2001) investigating patients' features which affect physicians' behavior. Interesting approaches were proposed by (Svatek et al, 2004; Razavi et al, 2007), adopting a data-mining method. Eventually, Case-based Reasoning has been recently proposed for the automated support of careflow management in general (Minor 2008, Weber 06), and to careflow monitoring in particular (Petridis 2009).

Careflow compliance detection and analysis involves both technical and socio-technical challenges. First of all, it requires the formalization of "best practice documents" into computational models (patterns, rules, etc.). This first challenge requires close collaboration between physicians and knowledge engineers, because documents are often ambiguous and include "hidden" knowledge. Second, the expected patterns and rules must be matched with patients' data, and this requires accessing the electronic patient record. Typically, data are stored in commercial and non-commercial products, requiring the interaction with different actors and data formats. A third challenge is to convince CfMS users to provide motivations for their non-compliance, even if this implies admitting some errors.

Innovation and Implications

We propose a novel, double view of careflow compliance based on different formalizations of guidelines and protocols: a graphical format (flowchart) and production rules (IF condition THEN action). The first one is used to find mismatches between the mined careflow and the expected process (e.g. a task present in the mined process but not in the guideline, or different sequences of tasks). Here, compliance is verified at a general "process" level. Conversely, rules are used to check for compliance at a more specific level, i.e. for each recommendation in a particular patient's care process. This allows a healthcare professional to reason about her/his behavior. In this context, an important issue that has not yet been systematically considered is how to present the results of non-compliance detection according to its severity degree, also based on specific healthcare settings. Another innovative aspect is the integration of multiple models. Although there are studies about multiple GL integration (Abidi 2009), all the existing studies on guideline compliance investigated only one GL at a time and do not consider the mixture of medical GLs and administrative regulation. We propose the development of methods to detect non-compliances in complex careflows, where this mixture is considered. Finally, a further innovation will be provided by a methodology able to intelligently exploit traces of careflow executions, by retrieving similar ones, and by automatically organizing them.

Implication 2. Accelerated developments of medical knowledge discovery and management, development of devices and procedures using in-silico environments.

Careflow Management System

Context and objectives

Careflows are indispensable to better understand how healthcare institutions operate, but one of the major advantages is to use them to manage patients' treatments. Once careflows emerge using a process mining approach, and after a thorough compliance verification, a flexible and compliant CfMS can be used to guide treatments, be used for patient information integration, and be used to control and guarantee the compliance of careflows instances with clinical practice GLs, protocols and healthcare institution's rules. The creation of a central semantic healthcare ontology will provide a 360º view on patients. By using semantic domain models, healthcare institutions acquire several benefits, such as the ability to perform inference and improve the decision-making procedure of healthcare professionals on the best treatments described by a careflow to follow.

The framework proposes the practical extension and implementation of a CfMS with: a) a flexible engine, b) a rule engine, and c) patient-based data integration. The flexible engine will provide a guidance mode, which will enable physicians to deviate from the strict execution of medical activities prescribed by careflows and, thus, undertake non-prescribed or non-compliant actions when warranted. The rule engine will support the relaxed execution of careflows using the guiding principle mode, encode clinical practice GLs, and identify the execution of non-compliance careflow instances.

State-of-the-art and challenges

Current process management systems (Cardoso and van der Aalst, 2009) have been developed as generic systems (e.g. Oracle Workflow, TIBCO InConcert, WebSphere MQ Workflow, YAWL) to be used in a broad spectrum of domains. As a result, a first restriction is the limited capacity to use careflows as blueprints to access data from healthcare systems using established protocols (e.g., HL7 and DICOM), and integrate the data into healthcare ontologies (e.g., SNOMED and Open Biomedical Ontologies Foundry). This integration has not been studied in the context of process-aware systems (Dumas et al., 2005). The development of CfMS with GL-based management can be achieved with the use of rule base systems (Panzarasa et al., 2007). Early work on the use of business rules and processes appeared after the introduction of the rule concept (Kappel et al., 1998, Knolmayer et al., 2000). So far, most work has been done in determining the usefulness of formal representational in workflow modeling, types of rules, rule consistency, rule reuse, enforcement of rules, and business rule modeling limitations (zur Muehlen and Indulska, 2010, Rosemann et al., 2006).

Three important challenges need to be addressed. First, the CfMS needs to be able to “speak” and “understand” XML-based communication languages (e.g., ASTN, DICOM, and HL7) and OWL-based knowledge representation languages to provide a 360° view on patients. Second, providing a 360° view on patients requires the merging, alignment, and extension of current ontology developments for healthcare, which need to be integrated into the core CfMS engine. Third, coupling a business rule engine for healthcare will enhance the CfMS by enabling it to understand and verify which clinical practice GLs and protocols are followed at runtime and which violate regulations.

Innovation and Implications

The CfMS proposed by our framework identifies three innovative aspects: a) support for XML and OWL-based integration, by extending the core careflow engine to support an efficient and (semi-)automated integration of syntactic information (e.g., healthcare XML-based standards) and semantic knowledge (healthcare OWL-based ontologies), b) direct use of healthcare ontologies to make better routing and scheduling decisions, by interoperating with healthcare ontologies to make the system adaptive, intelligent, and better serve patients by providing a 360° view on them. Valuable knowledge includes patient care, insurance policies, drug prescriptions, and clinical practices and best practices, and c) support rule-based guided and flexible enactment of careflows, by coupling a careflow engine with a rule engine. The formalization of clinical practices and GLs will enable the careflow engine to verify if instances follow best practices. This support for compliance is important since the costs for not providing a proper care are high (Perrier et al., 2008).

Implication 3. Improved interoperability of biomedical information and knowledge.

Careflow BI

Context and objectives

As careflow instances are executed by the CfMS, the generation and tracking of KPIs is fundamental for doctors and hospital administrators to take corrective actions. In the framework we suggest to: a) study the functional and non-functional requirements for careflow analysis by the actors of a healthcare institution (e.g., physicians, nurses, and hospital managers), b) design a data warehouse for careflow data, the associated patient data, and business data, and c) develop methods to analyze and mine data in order to evaluate careflows, detect deviations and similarities. The careflow BI system will automatically produce pre-specified reports, continuously feed dashboards with KPI values and support interactive analysis.

While business intelligence methods have been applied with great success to commercial organizations, their applicability to variable, low structured, multidisciplinary processes, has not been studied to a great extent. Careflows are processes with specific characteristics. First, there is no strict process model for a careflow since each patient is an individual case. Careflows are driven by the physicians' experiences and best practices. Second, careflows are orthogonal to the business processes of a healthcare institution but influence the KPIs as well. Third, careflows as a whole but also their single activities are associated to different types of data, ranging from unstructured data such as texts or high-resolution images to structured data such as encoded patient information. In the framework, we propose to (1) identify careflow-based KPIs which are used to improve decisions of the actors in a hospital such as physicians, nurses, managers, and technical personal, (2) identify dimensions in the available metadata (such as patient, disease-specific and organizational information) to classify careflows and allow for a combination with other measures, (3) design a representation for KPIs over non-uniform processes, (4) develop methods that calculate these KPIs, (5) develop real-time algorithms for grouping and KPI calculation to enable interactive careflow analysis.

State-of-the-art and challenges

Data Warehousing (DW) and On-Line Analytical Processing (OLAP) have been used for the integration and consolidation of multi-dimensional data analysis to provide fast and timely data analyses. In DW/OLAP architectures (Inmon, 2005; Kimball et al, 2008), data are pulled from data sources and prepared for the DW through an ETL (Extraction, Transformation, Loading) process. Ongoing research is directed towards living or real-time data warehouses (BIRTE, 2008), where changes in the source data are quickly propagated to the data warehouse, which thus contains current data. Data warehousing and OLAP has been traditionally applied to business data, which has led to the term Business Intelligence. In principle OLAP can be applied to all quantitative measures that can be classified into dimensions with different levels of granularity. Little research has been directed towards analysis and monitoring of processes (Grigori et al, 2004, Deutch, 2008, Beeri et al, 2007). Deutch (2008) has developed models for traces of web-based applications and a query language that allows querying the structure of the traces. Grigori et al. (2004) have developed methods and a tool for analysis and mining of business processes with known process models. Beeri et al, (2007) have designed a query language for monitoring business processes. All approaches base the analysis on known processes, which are modeled either in process modeling language like BPEL or directly in a web-based application.

We identify three major challenges. Firstly, meaningful similarity measures need to be developed for the grouping of ad-hoc careflows along different dimensions such as process and patient characteristics. Secondly, analysis methods and representations for the analysis' results for groups of heterogeneous careflows are needed. Finally, the analysis algorithms have to be fast enough to support interactive data analysis and should therefore use a fast main-memory data management system.

Innovation and Implications

The Careflow BI component proposed by in framework goes beyond the state of the art in three aspects: First, it allows analyzing less-structured careflow processes together with business and patient's data. A careflow-driven analysis groups careflows that are similar according to some careflow-specific characteristics and enables their comparison. Second, the KPI representation has to reflect the heterogeneity of the group of careflow processes it has been calculated for. Finally, since the user could specify a new classification of the set of heterogeneous processes on analysis time, the Careflow BI component has to support online classification and analysis.

Implication 4. Increased acceptance and use of realistic and validated models that allow researchers from different disciplines to exploit, share resources and develop new knowledge.

Careflow Collaborative Platform

Context and objectives

The four previous scientific and technological advancements create a wealth of healthcare information and knowledge. Mined careflows, worldwide best practices, treatment guidelines, and KPI indicators which are indispensable for decision-making need to be shared across healthcare departments. Introducing social networking capabilities into healthcare institutions changes the way information can be discovered, consumed, and delivered by caregivers. For example, doctors, nurses and administrators can create social networks of peers or join social networks of other healthcare professionals to share experience about adopted careflows, current performance indicators, and discuss the 360° data view of patients. Therefore, the framework provides a careflow collaborative platform, whose design exploits ideas and concepts emerging from social networks and social environments to create synergies that are yet to be described and quantified.

A careflow collaborative platform, which enables collaboration among all the organizational units, within a single healthcare institution or across institutions that are cooperating in the care delivery process of a same patient needs to be available. On the other hand, there is the need to create so-called "social communities of practice" for specific medical areas. For example, the platform can allow doctors to explain their decisions when they are not compliant with GLs. The systematic collection of these explanations is a means to continuously improve GLs implementation and versioning. Similarly, the community for a given specialty can view, comment, share, analyze compliance, and propose changes to recently mined careflows. Nurses can review the latest recommendations for treatments and be up-to-date on the most appropriate way to assist patients. Hospital administrators can be kept appraised of the effectiveness and efficiency of the careflows by means of personalized dashboards built from selected KPIs, and, in turn, provide additional change suggestions for improved performance.

State-of-the-art and challenges

The success of social networks is fostering researchers to exploit the same technologies for supporting communities of practice. This type of communities is an important catalyst of research, economic and social processes (de Moor, 2005) and is in fact driving the evolution of socio-technical systems (Wenger et al., 2002). In healthcare, these communities bring together medical experts, practitioners, patients and their families. The related work in this area is rather scarce. Nordqvist (2009) discusses how Web sites can help chronic patients with the daily management of their disease. Arenella (2010) uses Medscape, a commonly used online medical education provider, to disseminate palliative care education to health professionals. Networks of integrated care and research, that combine patients and expertise by sharing databases and disease registries on the Web, are being developed with the aim of harmonization of procedures, international epidemiological surveillance, and pharmaco-vigilance (Nurok, 2010).

The careflow collaborative platform must be able to conjugate careflows for case management with wider applications for social networking and social communities. Collaborative applications have traditionally faced resistance from healthcare professionals. Inconsistent user interfaces, unclear interaction patterns, and unintuitive designs are the major underlying causes. Therefore, there is the need to carefully consider the daily activities, computer literacy, interaction patterns with systems, and sociometrics of healthcare professionals. To quantify and study professionals' relationships to develop a sound social network-based collaborative platform needs to combine social theory and technology.

Innovation and Implications

An important innovation aspect concerns the involvement of all healthcare professionals that are joined in the collaborative platform. They are coordinated within a "community of practice" represented using medical social networks. This is a new approach since no social community of practice exists for the sharing of careflows and dealing with their improvement through formal methods. Up until now, most of these communities work in an "open-loop" modality, i.e. people can find suggestions, recommended paths, and so on, but there is no support for final users to be an active part in the improvement process model. The proposed framework aims at closing the loop, in such a way that caregivers and healthcare professionals' feedback becomes the starting point for such improvements. Members of communities need to share common-ground knowledge in order to discuss careflows based on common terminologies and concepts. Therefore, the platform and its tools rely on an ontology with a formal definition for concepts.

Implication 5. Reinforced leadership of industry and strengthened multidisciplinary research excellence in supporting innovative medical care.

Research methodology

Since the proposed framework for next generation e-health systems and services is intended to guide the creation of artefacts to serve human purposes, it is amenable to be researched using a Design Science approach, as discussed by (March and Smith, 1995). In this case, the concrete goal to improve careflows drives all building and evaluation efforts of the artefacts, namely with utility in mind.

March and Smith (1995) identify and describe four research outputs (artefacts in the form of constructs or concepts, models, methods, and instantiations) and four research activities (build, evaluate, theorize, and justify).

The authors state that the outputs can be "instantiated in specific products, physical implementations intended to perform certain tasks" that operationalize constructs, models, and methods to demonstrate their feasibility and effectiveness. They add that these instantiations may precede the complete articulation of the underlying artefacts.

Regarding the research activities, *Build* is concerned with constructing the artefact, taking into account its value or utility to a community of users. The key question in this activity is "does the artefact work?". After that, *Evaluate* is concerned with "how well does it work?". *Theorize* follows to "explicate the characteristics of the artefact and its interaction with the environment that result from the observed performance". In a nutshell, theorizing clarifies why and how the artefact works. Finally, *Justify* is concerned with gathering evidence to test the theory – justifying the explanation."

The researchers involved in the development of the proposed framework come from different areas, and include a team that establishes bridges to healthcare institutions where it can be deployed and tested. So far, the research activities have been centred on base artefacts. We developed concepts (such as careflow mining, careflow compliance, careflow management, and careflow BI), and started to experiment with methods to achieve the goals for each area. A first iteration of evaluation, theorization, and justification lead us to a model – the proposed framework – that will guide the evolution and integration of the base artefacts into an instantiation of a software platform in a healthcare institution.

Conclusion

Recent developments and programming paradigms have demonstrated the advantages of using process-driven systems (e.g., Amazon SWF), service-orientation (e.g., Web API and cloud services), and data analysis (e.g., using map-reduce) to build modern information systems. While these developments found a quick acceptance by competitive businesses – which have embraced them – they can also bring substantial benefits for the next generation of e-health systems. Nonetheless, this requires identifying e-health areas they can be applied more effectively.

We have described a framework centered on the concept of care workflows that brings together five key areas required for the development of next generation of e-health systems and services: careflow mining, to elicit actual enacted processes; careflow compliance, to ensure their alignment with clinical guidelines, and protocols; careflow management, to execute them in a guiding mode; careflow BI, to collect and process KPIs; and careflow collaboration.

The main limitation of the proposed framework is that it finds a better applicability in healthcare environments that already use process-aware IS or that have already adopted business process management initiatives.

Acknowledgements

This work has been partially funded by the ICIS project CENTRO-07-0224-FEDER-002003.

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