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ORIGINAL PAPER

Content architecture applications in healthcare

Suresh Chalasani · Pradeep Jain · Parag Dhumal · Hoda Moghimi · Nilmini Wickramasinghe

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Abstract Healthcare delivery is undergoing significant transformation in the United States. Many hospitals and clinics are utilizing electronic means for maintaining patient records. Implementation of electronic health records is now a prevalent activity at many healthcare organizations. Despite the use of electronic health records by many healthcare organizations, it is still difficult to obtain meaningful information from electronic data pertaining to healthcare. Intelligent content applications organize the data within a company make all the data in the organization searchable and retrievable for faster access. This paper therefore explores SOA (Service oriented architecture) and intelligent content architecture in an attempt to suggest better structures that enable retrieval of related data from myriad sources within a company. While intelligent content applications are being slowly developed for areas such as electronic publishing, its use in healthcare organizations has been limited. This paper discusses applications of intelligent content architecture for the healthcare domain.

Keywords Content architectures · Service oriented architecture · Intelligent content · Knowledge management · e-Health · Electronic health records

S. Chalasani · P. Dhumal
Department of Business, University of Wisconsin-Parkside, Kenosha, WI, USA

P. Jain
Ictect, Inc., Racine, WI, USA

H. Moghimi · N. Wickramasinghe (✉)
College of Business, RMIT University, GPO Box 2476, Melbourne, VIC 3001, Australia
e-mail: nilmini.wickramasinghe@rmit.edu.au

N. Wickramasinghe
e-mail: nilmini.work@gmail.com

H. Moghimi · N. Wickramasinghe
Epworth HealthCare, Melbourne, Australia

1 Introduction

Globally, healthcare expenditure as a percentage of Gross Domestic Product (GDP) by 29 members of the Organization for Economic Cooperation and Development (OECD) rose from 5.0 to 8.1 %, between 1970 and 1997 [1]. Moreover, since 2000, total spending on healthcare in these countries has been rising even faster than economic growth [2]. To address this significant problem and thereby provide value driven superior healthcare, most, if not all, countries within the OECD are investigating possibilities for a variety of e-health implementations. Such e-health solutions include various wired and wireless solutions including electronic medical records, e-prescription systems, PACS and other lab/radiology systems as well as various billing and practice management type systems. Given this in-flux of technology into healthcare delivery, the most recent Obama healthcare reform identifies that a key consideration of the use of technology in healthcare delivery should be concerned with meaningful use [3]. That means, not only organizations need to implement electronic health records (EHRs), but they should demonstrate that the EHRs are used in a meaningful way to conduct their operations.

Despite the increased implementations of EHRs, healthcare data has not been organized for intelligent data retrieval. For example, to study the effectiveness of two drugs, say Crestor and Lipitor, for reducing cholesterol in patients with heart disease, it is currently difficult to mine the data from the EHRs. On the other hand, an intelligent content architecture can make such information more readily available.

Content architecture refers to the architecture that organizes and labels the components of content so that they are useful, reusable, and effective [4]. According to experts, intelligent content is structurally rich and semantically aware, and is therefore automatically discoverable, reusable, reconfigurable, and adaptable. Healthcare data is rich in its abundance, and it becoming structurally rich be-cause of the increasing abundance of EHR implementations. Content becomes semantically aware when the content is tagged with metadata to indicate the type of content it has. For example, healthcare data, when it tagged to indicate whether it is patient-prescription data, patient-history data, patient-medication data, pre-existing conditions data, it becomes semantically aware.

2 EHR implementations and meaningful use

A recent survey of physicians from ten different countries conducted by the Commonwealth Fund showed that the USA showed the biggest leap in the use of electronic health records [5]. Table 1 shows the change in the use of EHRs by primary care physicians for these ten countries (Table 1). From this table, it can be seen that the USA made a very big leap in EHR usage since 2009. One reason for this is because the Centers for Medicare and Medicaid Services (CMS) in the US have been awarding incentives to physicians for using and demonstrating meaningful use of EHRs in their practices. Some of the major products for EHRs in the USA include Epic and Cerner.

Some of the challenges of EHR implementations include training physicians and staff in the new clinical processes that come with EHRs. A recent best practices study (conducted on Oct. 31, 2012) revealed that 60 % of practices claimed that EHR implementations negatively affected their patient flow [3].

Table 1 Percentage of EHR use in 10 different countries [4]

Country	% physicians using EHRs in 2009	% physicians using EHRs in 2012
Australia	95 %	92 %
Canada	37 %	56 %
France	68 %	67 %
Germany	72 %	82 %
Netherlands	99 %	98 %
New Zealand	97 %	97 %
Norway	97 %	98 %
Switzerland	N/A (did not participate in the 2009 survey)	41 %
United Kingdom	96 %	97 %
United States	46 %	69 %

In the same survey, only 50 % of the practices claimed that their office staff was adequately trained for the EHR implementations; only 54 % claimed that the physicians were adequately trained. Also, only 50 % of the practices claimed that the training modules met their expectations.

In 2010, federal government defined 25 objectives that healthcare providers need to meet to demonstrate the meaningful use of EHRs. If the providers are able to demonstrate meaningful use of EHRs, they stand to gain tens of thousands of dollars in incentives for the adoption of EHRs. Out of the 25 objectives, 15 objectives are deemed core objectives and are outlined below [6].

- Use computerized physician order entry (CPOE) for medication orders directly entered by any licensed health care professional who can enter orders into the medical record per state, local and professional guidelines.
- Implement drug/drug and drug/allergy interaction checks.
- Maintain an up-to-date problem list of current and active diagnoses.
- Maintain active medication list.
- Maintain active medication allergy list.
- Record and chart changes in vital signs, including: Height, Weight, Blood pressure, Calculate and display BMI, Plot and display growth charts for children 2–20 years, including BMI.
- Record smoking status for patients 13 years-old or older.
- Provide patients with an electronic copy of their health information (including diagnostic test results, problem list, medication lists, and medication allergies) upon request.
- Capability to exchange key clinical information (for example, problem list, medication list, medication allergies, and diagnostic test results), among providers of care and patient authorized entities electronically.
- Protect electronic health information created or maintained by the certified EHR technology through the implementation of appropriate technical capabilities.
- Generate and transmit permissible prescriptions electronically (eRx).
- Record demographics, including: preferred language, gender, race, ethnicity, date of birth.
- Implement one clinical decision support rule relevant to specialty or high clinical priority, along with the ability to track compliance that rule.
- Report ambulatory clinical quality measures to CMS or states.
- Provide clinical summaries for patients for each office visit.

There are three stages in which hospitals can demonstrate meaningful use. These three stages are illustrated in Fig. 1.

As can be seen from Fig. 1, EHR usage gradually needs to be increased further and further in each stage to qualify for

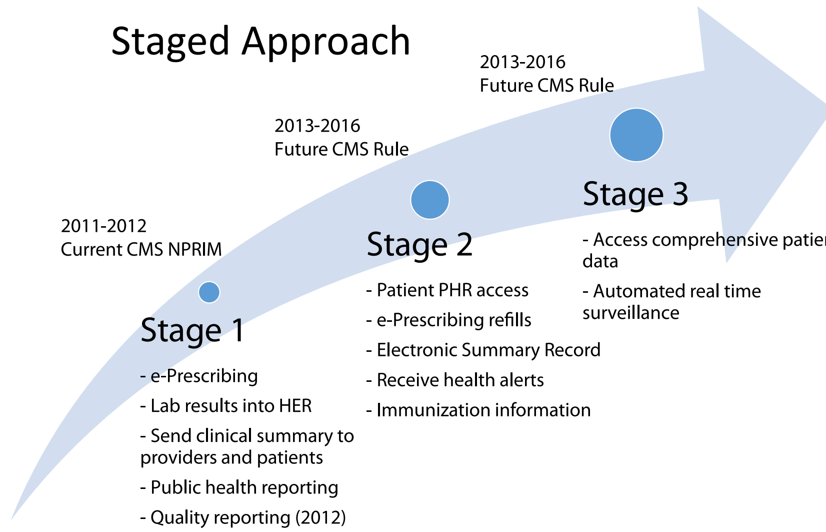

Fig. 1 Stages for demonstrating meaningful use of EHRs (Adapted from [7])

federal incentives. As EHR implementations continue to rise, more and more data will be available for clinical decision making.

3 Background of SOA and SOE

Over the last few years, web services and the service-oriented architecture (SOA) have become main themes in IT across many industries [8]. Service oriented architecture can be defined as a framework to integrate business processes and supporting IT infrastructures into secure, standardized components services that can be reused and combined to address changing business activities and priorities [9]. Gens [10] believes the goal of investing in SOA is to be a fully deployed Service-Oriented Enterprise (SOE) in integrating internal and external processes and services—processes of the firms as services (Gens []. The SOA is considered as highly suitable for a new software design model for the healthcare industry [11]. SOA for healthcare integration helps healthcare organizations lower operating costs and speeds time-to-market by delivering a consistent user interface, management console and monitoring environment, as well as healthcare libraries and templates for healthcare customer projects [8].

Nasr et al. [12] studied business investment in SOA in 2010. Their study presented that more than half of business sectors investing in SOA have had anticipated or more than expected benefits and less than half have had less than expected benefits or have not deployed it on operational systems, as we depict in Fig. 2 [12].

A literature analysis conducted by Lawler [13] examines Levels of Maturity of SOA in 15 business firms of the 2010 and 2007 case studies and literature studies (Fig. 3) [13].

As presented in Fig. 3, more SOA studies in 2007 and 2010 are related to deployment and exploitation of services based on SOE while in the other firms the most conducted studies in the same years are regarding the process integration, service architecture, restructuring of organization and expansion of web services.

In analyzing and continually enhancing fundamental activities of the operation of business firms, the program management methodology is defined by Lawler and Howell-Barber [14]. It is a disciplined Methodology for Enabling Service-Oriented Architecture (Fig. 4), described in frameworks of best practices of governance, communication, product realization, project management, architecture, data management, service management, human resource management and post implementation on initiatives or projects of SOA [13] (and Table 2). Hence, as shown in Fig. 4, multiple aspects including governance, communications, product realization to mention few are supported. This is indeed pertinent for healthcare contexts.

SOA infrastructures have clearly matured and are at different stages of delivering on the promise of cost savings, efficiency, and business results [15]. Blobel et al. [16, 17] and Lopez and Blobel [18] discuss methods to make EHRs interoperable. Lopez and Blobel present a methodology to achieve semantic interoperability of health information systems and their components. However, the ground reality at this time in the United States is that the EHR interoperability is minimal or non-existent. Healthcare organizations are still in various stages of evolution of emerging SOAs without any deployed outcomes in this context. Therefore, in an attempt to overcome this issue we propose to identify key service oriented architectural requirements in healthcare context, in order to enhance care performance. The SOA applications presented in this paper is *one way* to obtain meaningful healthcare data from myriad sources within an organization or from different organizations for clinical and research purposes.

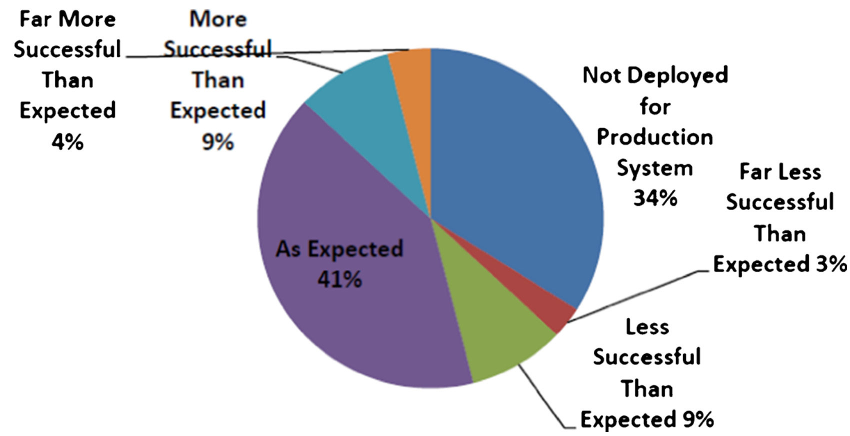

Fig. 2 Impact of SOA deployment in different business sectors (Adapted from [12])

4 The need for SOA in healthcare context

The aim of health information systems is primarily to contribute to a high-quality and efficient patient care system [19]. This aim is centred towards the patient, so it is first and foremost a patient-centered approach and then focuses on medical and nursing care, while the administrative and management tasks must support and facilitate such care [20]. However, besides increasing the number of information systems, some issues are also developing such as:

- Lack of interaction between these systems
- Duplications
- Lack of integrated systems
- Lack of a clinical information flow between the system users
- Lack of aggregations

Therefore to address these issues, SOA towards SOE appears to be a prudent technological solution to make a robust architecture obtaining the best care outcomes. To design the healthcare service oriented architecture, a managerial approach should be used as a lens to find the value stream of IT solutions

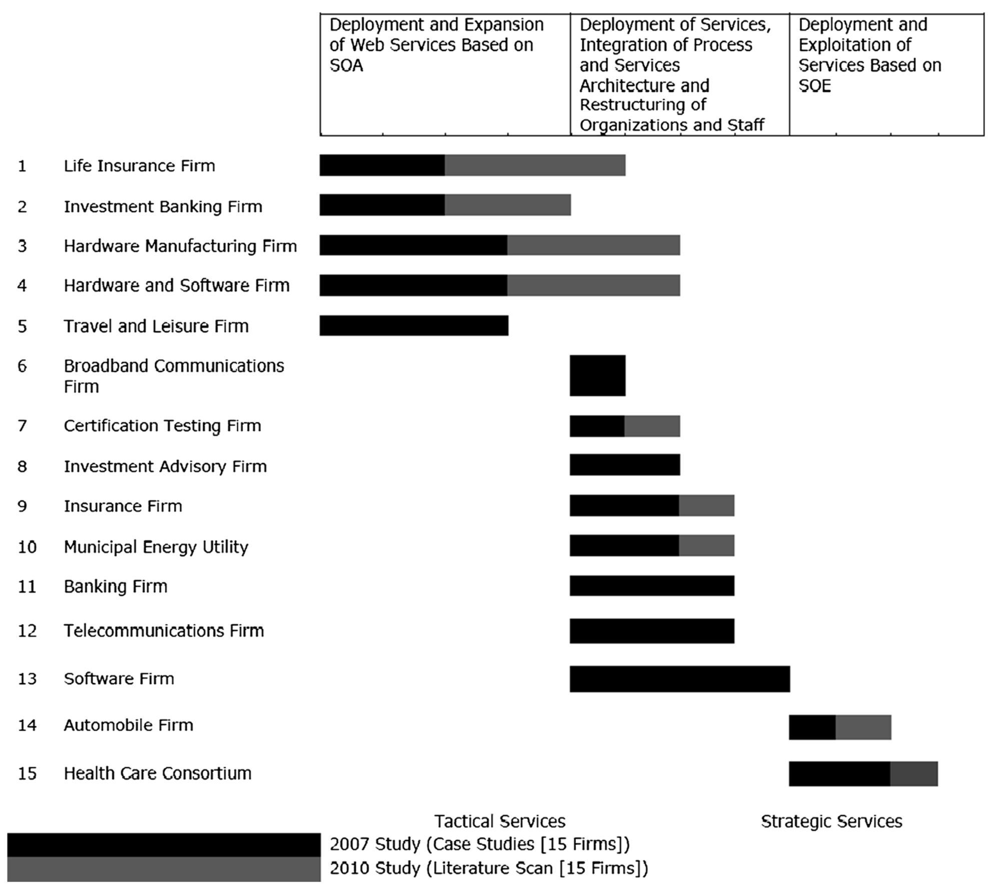

Fig. 3 Levels of Maturity of SOA (Adapted from [13])

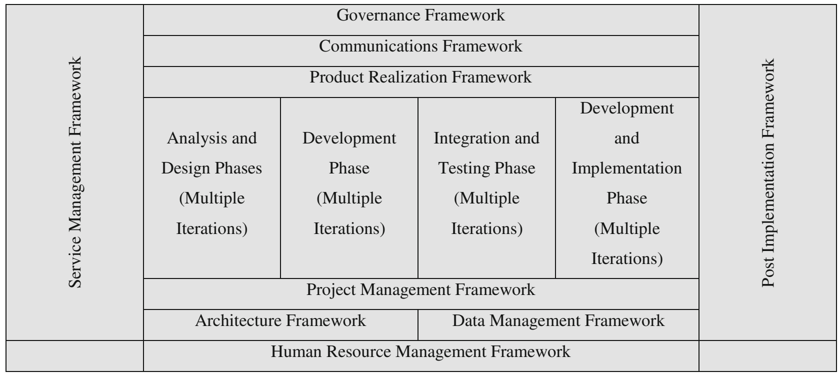

Fig. 4 The significant role of Program Methodology frameworks to explore the SOA strategies or techniques in different firms

Table 2 Frameworks of program management methodology towards SOA deployment (Adapted from [14])

Frameworks	Impacts to SOA deployment
Governance	Enables alignment of processes and services with business strategy and results in evolution towards SOE
	Ensures services conform to consistent corporate SOA strategy supporting business strategy of firm
	Facilitates learning of program management methodology
Communications	Enables emphasis on business criticality of SOA of business firm, articulated by Chief Information Officer (CIO), if not Chief Executive Officer (CEO)
	Ensures collaboration of business and technical staff in continued plan on endeavor, coupled
	Enables emphasis on business criticality of SOA of business firm, articulated by Chief Information Officer (CIO), if not Chief Executive Officer (CEO)
Product/service realization	Enables analysis and design, development, integration and testing, and deployment and implementation of SOA and Is core of established project management methodology
	Is coupled with other frameworks and ensures focus of projects is on business processes to be evolved into SOA and not on technology
	Program to be realized may be implemented in interlinked iterations of internal department application projects to external firm process integration projects
Project management	Enables delivery of projects of SOA
	Ensures changes in business strategy are applied as appropriate on projects of SOA
	Ensures processes and services are functioning and implemented as planned in strategy
Architecture	Enables compliance of business processes with SOA model
	Ensures evolution from conversion of functions into services, creation of component services and integration into composite services, integration of internal applications, internal services and external services, to on-demand services in a gradual SOE
	Ensures seamless integration of hardware and software conforming to service standards and technology
Data management	Enables behaved SOA data services not disruptive of applications of firm
	Enables implementation of services, based on access, availability, breath and accuracy of data already in databases of applications
	Ensures consistency of data
Service management	Enables continued conformity and coordination of processes and services to business strategy
	Is coupled with product realization on new projects of SOA and ensures requirements for new processes and new services, or revisions to them, are not redundant with existing processes or services
	Ensures reusability of services
Human resource management	Enables identification of new and revised Responsibilities and roles of business and technical staff on SOA
	Ensures education of business and technical staff on change in culture of service orientation, and technical staff on technology of SOA, is furnished throughout projects of SOA
Post implementation	Enables service and process life cycle tasks following product realization
	Ensures availability of applications and services and of technologies, tools and utilities of SOA
	Is formulated in Service Level Agreements (SLA) between technology department, internal business departments and business units

in healthcare and make sure what the main components of this architecture are.

In the next section, we discuss existing standards for healthcare data and its interoperability.

5 Existing healthcare architectural and interoperability standards

Health Level 7 (HL7) is a healthcare systems organization that promotes interoperability for exchanging healthcare data. HL7 provides a common interface among healthcare and develops messaging standards for communication between disparate healthcare systems. While HL7 standards do not provide a programming language, it discusses messaging standards to communicate healthcare data such as patient diagnosis results, physician order entry, patient scheduling etc.

HL7 also provided consolidated clinical architecture (C-CDA) standard for implementing stage 2 meaningful use requirements of EHRs. CDA provides a common architecture, coding, semantic framework, and markup language for the creation of electronic clinical documents [21]. CDA's goal is to provide a structure by which different types of healthcare data elements can be captured, stored, accessed, displayed and transmitted electronically for use and reuse in multiple formats. CDA's focus is on encoding the data for interoperability, and it does not discuss how the data should be transported from one healthcare source to another.

Different standards organizations published sometimes duplicate and sometimes conflicting standards for healthcare data. The C-CDA focuses on providing a consolidated standard for healthcare documents. C-CDA developed consolidated standards for several healthcare documents including: Consultation Note; Discharge Summary; Imaging Integration and Diagnostic Imaging Reports (DIR); History and Physical (H&P); Operative Note; Progress Note; Procedure Note.

C-CDA standards are useful for achieving some of the meaningful use stage 2 requirements. For example, when transitioning a patient to another care setting, one of the MU 2 requirements is that the Eligible Professionals (EPs) or Eligible Hospitals (EHs)/Critical Access Hospitals (CAHs) should provide a summary care record. The C-CDA standard provides several templates that could be combined together to fulfill this requirement [21]. In the next section, we discuss some applications of intelligent content architectures in healthcare, and the possibilities that intelligent content architectures can provide.

Ontologies help provide structure to clinical data [22]. An ontology is a structural framework or representation of knowledge within a given domain. Ontology specifies the concepts, relationships, and other distinctions that are relevant for modeling knowledge. From a computer science and technology perspective, ontologies can be specified in the form of classes, their attributes, the relationships among classes, and rules governing classes and their attributes.

Systematized Nomenclature of Medicine (SNOMED) is the most widely recognized nomenclature (or naming system) in medicine. The SNOMED Clinical Terms (SNOMED CT) provides a set of concepts and relationships and clinical reference terminology to consistently capture detailed clinical information. SNOMED CT has several components including the following:

- A concepts table containing 344,000 concepts with unique meanings and formal logic-based definitions organized into hierarchies. Some of the concepts include "Clinical finding/disorder", "Organism" etc.
- A descriptions table containing more than 913,000 English-language (660,000 Spanish-language) descriptions or synonyms for flexibility in expressing clinical concepts.
- A relationships table containing approximately 13 million semantic relationships to enable robust reliability and consistency of data retrieval.

Logical Observation Identifiers Names and Codes (LOINC) is a widely used standard for representing laboratory data in ordering lab tests and reporting lab test results. It has been further enhanced to include other observational data such as the vital signs. The RxNorm is a standard notation for clinical drugs. RxNorm was developed by several organizations such as the FDA, Veterans Administration, The National Library of Medicine in consultation with organizations such as HL7.

6 A process for obtaining intelligent content from healthcare data

As more and more clinics/hospitals implement EHRs in the United States, health data is available in the electronic form for tens of millions of patients. This health data can be utilized for research purposes if it is transformed into intelligent content. Below we discuss a step-by-step process to obtain intelligent content from healthcare data. This process is illustrated in Fig. 5.

1) Make the EHR data anonymous. This is a fundamental step to comply with the privacy laws in the United States that protect patient privacy. The Health Insurance Portability and Accountability Act of 1996 (HIPAA) provides myriad privacy and security rules with which healthcare organizations need to comply. When exporting data to external entities, this law requires de-identification of protected health information. That is, de-identified/anonymized health information should not identify the individual to whom it belongs.
2) Combine the anonymized data from multiple EHR systems into one single master data file. Different hospitals and clinics are currently implementing different EHR

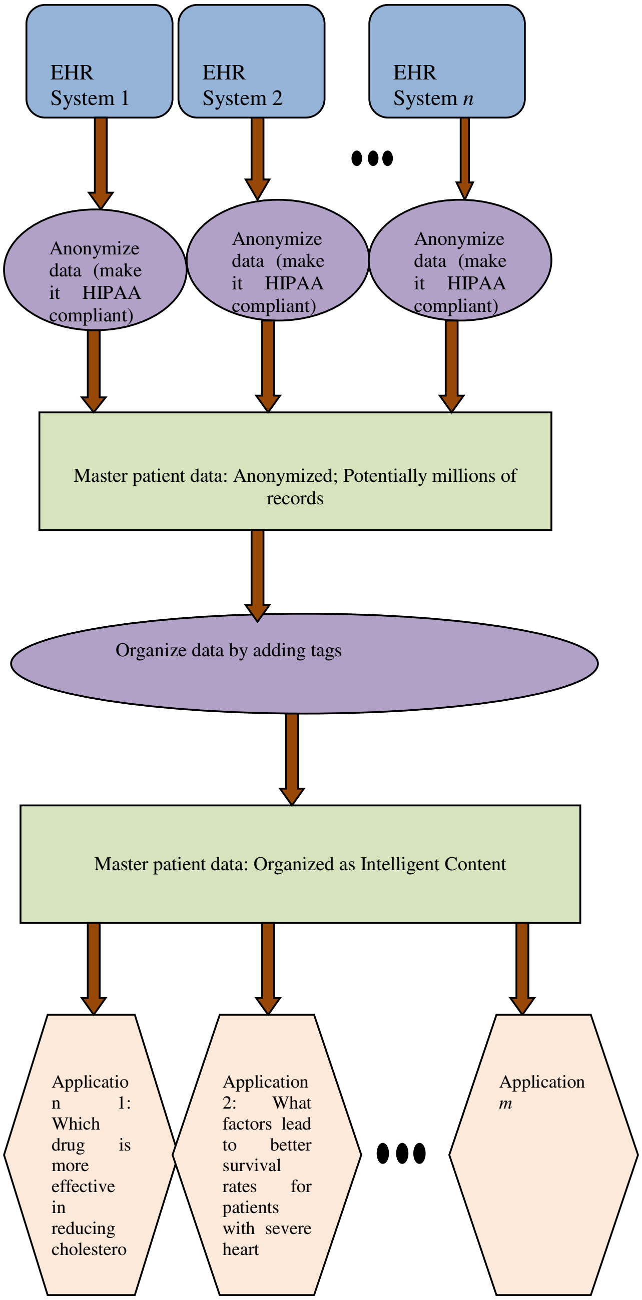

Fig. 5 A process for obtaining anonymized tagged, intelligent content from healthcare data

systems. For example, one hospital might implement Epic software while another might implement Cerner. Obtaining anonymized data from each system and bring them together using such technologies as XML (extensible markup language). Preparing data in XML format helps create content in a completely open and portable format.

3) Tag data and organize data. This step helps make the data intelligent. For example, data related to specific diseases such as cancer or heart disease and the medications/ therapies undergone by these patients for the diseases they have can be tagged. There are multiple advantages of tagging data, which are discussed later in this section. Tagging of data can use existing ontologies such as SNOMED and RxNorm. The approach we propose can work with the existing method of classifying clinical concepts and clinical drugs. For example, if the data out of the EHR system is already tagged according to RxNorm for the clinical drugs taken by the patient, those tags can be definitely used in our approach. Further, the SNOMED CT data tags can be used for classifying and organizing patient data according to clinical concepts.
4) Used tagged intelligent data for multiple applications. For example, one application can sift through tagged data for the effectiveness of cholesterol drug Crestor versus the effectiveness of drug Lipitor in reducing the cholesterol amounts. Another application can compare the effectiveness of radiation therapies in cancer patients and recommend best practices in terms what works the best.

The process below can be implemented using different technologies. Several industry partners are currently offering technologies for transforming content into intelligent content. One such organizations is Ictect, Inc. located in Racine, WI, USA. Ictec, Inc. currently provides intelligent content services to a variety of organizations including the US Department of Defense.

Intelligent Content is enabled by broad enterprise-level adoption of XML. Intelligent Content is granular at the appropriate level, semantically rich, useful across applications, and meaningful for collaborative interactions [23]. Forrester championed the notion of content architectures for marketing professionals, as a "framework to bridge the contextual and semantic gaps." Intelligent content architectures for healthcare data can provide the following benefits for organizations and stakeholders that adopt them:

- Single source of truth for the content and related information; that is, healthcare data for millions of patients with complete list of history, prescriptions, diseases, treatments, allergies is available as a single source in an open and easily transferable format.
- Competitive advantage by leveraging intelligence in the content; that is intelligent healthcare data can be utilized by organizations for competitive advantage. For example, a recent trend in healthcare delivery is the accountable care organization (ACO). ACOs are groups of doctors, hospitals, and other health care providers, who come together voluntarily to give coordinated high quality care to the Medicare patients they serve. By utilizing intelligent content, ACOs can demonstrate to the Centers for Medicare and Medicaid that they meet the standards of care required by ACOs.

- Future-proof content by using the XML standard. By using the XML standard, healthcare organizations can be at the forefront of technology for intelligent content.
- Sustainable cost reduction by having optimized business processes. For example, intelligent content can be searched for therapies and processes that work for patients, thus reducing the cost of healthcare delivery in the United States. Healthcare costs have been exceeding 16 % of the GDP in the US in recent years. Cost reduction by optimizing healthcare processes and promoting preventive care and arriving at effective treatment options for chronic diseases can be accomplished using intelligent healthcare content.
- Multi-channel delivery of content to popular media types and channels. For example, the same healthcare data, using intelligent content, can be delivered to multiple platforms such as mobile devices (cell phones, iPads etc.) versus laptops. Let us consider the simple example of a researcher seeking information on how many diabetes patients are on Metformin versus Onglyza medications. Intelligent content (appropriately tagged for these medications) can provide answers to such questions in a matter of seconds. The display of these results could be as a pie chart on cell phones and in a tabular format on laptops.

7 Concluding remarks and directions for future work

Few would disagree that healthcare delivery in the US and globally is at a cross roads [24, 25]. Costs are escalating and quality is too often a growing concern. In order to address effective and efficient patient-centric healthcare delivery, it is necessary to focus on how to provide value. In the Information age this is only feasible by embracing technology to enable superior healthcare delivery. Several research projects are currently underway in the US to use more mobile devices in healthcare for diseases such as diabetes and hypertension [26, 27]. There is a significant need to integrate data from multiple healthcare sources and to make the data more intelligent by appropriately tagging the data.

In this paper, we articulated a vision by first introducing the concept of service oriented architecture and service oriented enterprises and then focusing on a process to make the healthcare data more intelligent by gathering the data from multiple sources, de-identifying/anonymizing data, tagging the data and using it for multiple applications. The process we outlined in the previous section can identify healthcare transform healthcare into intelligent content which adheres to the following principles outlined by multiple researchers including Rockley and Gollner [23].

Structurally rich Different healthcare pieces of data can be tagged, thus making searches much easier to implement. For example, one can easily identify the list of e drug allergy reactions in cancer patients to specific drugs.

Semantically categorized Healthcare data can be semantically tagged with metadata which indicates the kind of data it contains. For example, we can tag data form EHRs as prescription data versus x-ray data versus lab-results data. Semantic tagging of data enables data to be searched easily. Questions such as "what is the average length of time patients have been on the cholesterol medication Crestor before their cholesterol levels reduced by 25 %" can be answered due to semantic tagging of data.

Easily discoverable and efficiently reusable Structurally rich and semantically tagged data is easier to find and reuse.

Once obtained, intelligent content can be used for many applications. Any new data can be more easily translated into intelligent content format using the structures created during the first-time data transformation.

The University of Wisconsin-Parkside, Ictect, Inc. and RMIT are currently exploring a project to develop intelligent healthcare architectures. As part of this project, we are seeking healthcare organizations as partners to implement the vision outlined in the previous section. We believe the process of transforming healthcare data into intelligent content architectures will enable healthcare organizations in a significant manner. For example, if healthcare organizations need to demonstrate that they have met the meaningful use criteria set by the Centers for Medicare and Medicaid services (in order to receive incentives), intelligent healthcare architectures can provide reports on the following:

- Number of physicians who used EHRs in given a time period
- Number of patients whose records/data were entered into EHR systems when they visited healthcare organizations
- Number of prescriptions filled out in EHRs by physicians
- Reduction in allergic reactions in patients due to drug-to-drug interactions
- Reduction in the amount of time spent in recovering from a specific type of surgery by patients

The above are some examples questions that can be easily answered by intelligent content architectures. We are currently developing a prototype of healthcare content architectures. We note though, in closing, that this is only the beginning and much work is required to ensure a seamless and successful architecture ensues. In particular, we realize that tagging using controlled domain terminologies and/or ontologies will be challenging. Our future work will try to develop some strategies in this regard.

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Conflict of interest The authors declare that they have no conflict of interest.

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