Novel Connected Health Interoperable Layered (CHIL) Model

Monika Simjanoska[1], Jugoslav Achkoski[2], Ana Madevska Bogdanova[1], and Vladimir Trajkovik[1]

[1] Ss. Cyril and Methodious University, Faculty of Computer Science and Engineering, Rugjer Boshkovikj 16, 1000 Skopje, Macedonia
{monika.simjanoska,ana.madevska.bogdanova,trvlado}finki.ukim.mk
[2] Military Academy "General Mihailo Apostolski", Vasko Karangelevski bb, 1000, Skopje, Macedonia
jugoslav.ackoski@ugd.edu.mk

Abstract. In this paper we present a novel design of a Connected Health paradigm that solves the interoperability and transitivity issues by introducing layers - the Connected Health Interoperable Layered Model (CHIL Model). The goal of our cylindric CHIL model is achieving a new quality of telemedical systems whether they are already developed or in progress. Building new systems can be performed by direct implementation of its components in each disk (layer) of the cylinder. The existing systems can be mapped in two moduses, a Distributed mapping along multiple disks or Focused mapping on a single disk. Considering both cases, using the CHIL Model, result in a complete stand-alone system that can be successfully included in the Connected health Environment. As a prove of its leverage, we discuss two case studies that comprise both distributed and focused mapping of existing systems.

Keywords: Connected Health, Telemedicine, Layered Model.

1 Introduction

The World Health Organization (WHO) definition of health that has not been amended since 1948, states that health is a state of complete physical, mental and social well-being and not merely the absent of disease or infirmity [1]. This definition has been attacked as inadequate because of its social dimension making it to correspond much more closely to happiness than to health. To avoid the conflict, Sarraci proposes another definition stating that health is a condition of well being free of disease or infirmity and a basic and universal human right [2]. This description provides an intermediate concept linking the WHO's ideal to the real world of health and disease as measurable by means of appropriate indicators of mortality, morbidity, and quality of life [2]. Those measurable indicators are something according to which we can make models nowadays and use them to predict the health condition.

Shukla et al. [3] made an effort to appropriately define Health Informatics (HI). They present the Americal Medical Informatics Association definition

S. Loshkovska and S. Koceski (eds.), *ICT Innovations 2015*,
Advances in Intelligent Systems and Computing 399,
DOI: 10.1007/978-3-319-25733-4_13

which says that HI is "all aspects of understanding and promoting the effective organization, analysis, management and use of information in health care". Canada's HI defined it as "intersection of clinical, IT and management practices to achieve better health". They all agree that HI can be divided into four main subfields:

1. Clinical care;
2. Administration of health services;
3. Medical research, and
4. Training.

Once the HI is defined, the health-care becomes a combination of alarms, sensors and other equipment to monitor people's physiological data as blood sugar, pressure, heart rate, stress level, lung function, etc., and help them live independently. That combination is referred to as telehealth/care, whereas the delivery of health-care services when the distance is a critical factor is called telemedicine [4]. All these terms are covered by an approach to health-care delivery that uses a wide range of information and collaboration technologies to facilitate the accessing and sharing of information, as well as to allow subsequent analysis of health data derived from electronic medical records and connected biomedical devices across healthcare systems called Connected Health (CH) [5]. CH does not encourages only management of patient's clinical data, but also the communication and collaboration among all the entities involved in a patients health. This feature introduces some barriers that can stand in the way to CH:

- Systems and policies;
- Organization and management;
- Clinicians and end users, and
- Patients and the public.

The ambition of CH is to ensure the confidentiality of personal health data and to connect all parts of a healthcare delivery system through interoperable health information system, so that critical health data is available anytime and anywhere [5]. Kovac in his study [6] elaborate interoperability in a way that it shouldn't be understood as simply technical connectivity, but true interoperability enables health information and medical expertise to be exchanged among clinicians, patients and others to further understanding. In order to achieve interoperability, the CH system need to sustain security and privacy, transparency, preservation of information, re-usability, technological neutrality and patient centricity.

In this paper we present the scope of CH by introducing a novel designed layered model, each layer presenting different entities, their sub-layers and the interconnections between them.

The goal is to create CH model that will overcome the before mentioned barriers and achieve interoperability as described by Kovac [6]. Even more, the proposed design allows transitivity between the different layers without preserving the hierarchy of the model. Because of its properties, the proposed model is referred to as Connected Health Interoperable Layered model - CHIL model.

In order to show both the horizontal (on one layer) and vertical (among the layers) transitivity and the interoperability, we analyze two case studies. The first case study presents a distributed integration of a new state-of-the-art telemedical IS - SIARS (Smart I (eye) Advisory Rescue System) [7] and the second one describes a case of a focused implementation of an existing classification system [8] in a single layer of the CH model.

The rest of the paper is organized as follows. In Sect. 2 we present the existing connected health models as well as telemedicine systems and prediction approaches. The novel CHIL model and its components are presented in Sect. 3. In Sect. 4 we present two case studies to show the flexibility of CHIL when integrating existing systems. The conclusion and the possibilities for further development of CHIL are presented in Sect. 5.

2 Related Work

In this section we present some recent health models that leverage the information technology and have contributed to better understanding of the necessity of this kind of models integration in people's lives.

Collaborative Health-Care System (COHESY) is a novel model for monitoring health parameters and physical activities developed by Trajkovik et al. [9]. The approach itself is original by the fact that it is not only predictive, but also introduces collaborative filtering module which means that the entities can communicate and exchange experience via social networks. Designed to increase self-care regarding the health, the model combines data from patient's current state and environmental sensors. Given the measure, the model automatically adjust threshold parameters and sends notifications or emergency call if necessary. The collaborative algorithm behind COHESY is explained via two types of scenarios. A simple one that considers sensors connected to a smartphone and data presented to patients and doctors, and a smarter scenario where the model makes conclusions about the current health condition of the patient based on both the sensors and integrated expert knowledge [10].

When talking about an integrated advice giving system based on prior knowledge, Jovanovik et al. [11] did a remarkable work by stressing out the importance of knowing how the negative food - drug interactions are spread in various cuisines. In the focus of their research is the patient who is under a treatment with particular drug and an advisory mechanism of the possible negative food - drug interactions and also the cuisines that should be avoided while the patient is under treatment.

Besides the challenge of making a system that is capable of giving advices, the authors [10] aim to automate the process. An accurate predictive algorithm is still a great challenge in the healthcare environment. As the authors state in [12], healthcare environment is information rich, but knowledge poor. There is still lack of analysis tool to discover hidden relationships and trends in data.

The current state of chronic disease data and analysis is being investigated by Sullivan et al. [13]. They define a simple model for chronic disease to be disease free at the beginning, then preclinical, afterwards comes the clinical manifestation and the final stage is everything that follows-up. By using statistics and Machine Learning (ML) techniques to model the chronic disease, they inspect the probability of manifestation of the each clinical stage based on the risk factors as age, gender, smoking, blood pressure, cholesterol etc.

Another very challenging field of research is the creation of prediction models in terms of risk and costs of diabetes. Farran et al. [14] performed a research on data from Kuwait to assess the risk of type 2 diabetes. They present a fact that one in ten suffers from diabetes and one in three from hypertension. Thus, their aim was to model the increased proneness in diabetic patients to develop hypertension and vice versa. In achieving the goal they use four ML techniques including logistic regression, KNN, multifactor dimensionality reduction and SVM. Their work ascertain the importance of ethnicity.

Health-care cost projections for diabetes and other chronic diseases are discussed in [15]. The work examines the relationship between chronic disease on current and projected health care costs. Diabetes is found to be most suitable for epidemiological modeling to analyze long-term nature of the development. The models are combined with clinical trial data and are used to easily extrapolate clinical trials over the lifetime of patients. There are variety of models proposed. Most notable is the Archimedes model that differs from the others in that it sets out to account for basic cellular and organ functioning to predict the risk of complications.

3 The Novel CHIL Model

The model proposed in Fig. 1 is based on the challenges that are mostly elaborated in [5]. The idea behind the cylindric representation of CH is to depict all sub-layers and the relations amongst them.

3.1 Policy Layer

A clear strategies and protocols that are aligned with the wider health reforms are necessary for achieving desired health outcomes. The policies should be flexible and thus the regions or local institutions will be encouraged to be innovative and take their own approaches to the development of health-care IT systems that will meet the local demands. Policies comprise education and training as essential in improving the expertise for achieving appropriate integration of the clinicians and administration in the CH system. This layer serves to the economy layer by providing it with the suitable costs plans for actions.

3.2 Economy Layer

The economy layer consists of protocols for management, funding mechanisms and business cases. It connects the policies and the users by providing the appropriate and cost-efficient strategies to maximize the potential of limited funding

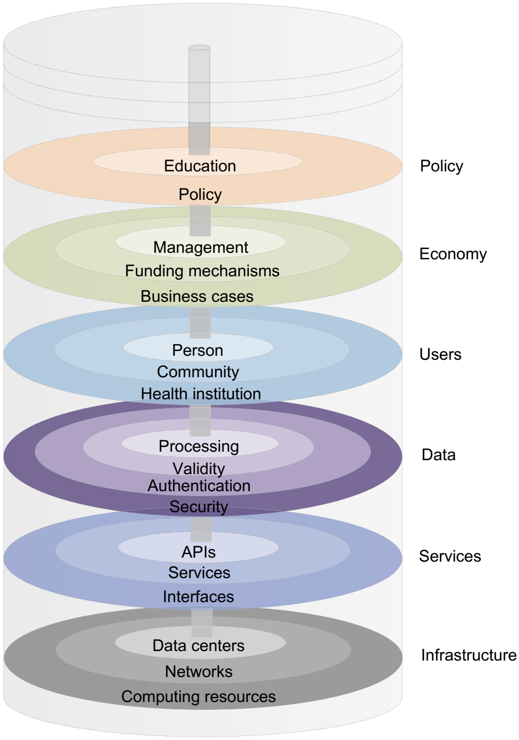

Fig. 1. The CHIL model

to ensure quality and efficiency of the health institutions. All the activities in this layer aim towards linking the investments directly to the achievement of health outcomes. The management should rely on innovation schemes that encourage integration and coordination across organizations by creating coordinating bodies to manage required cultural and organizational changes.

3.3 Users Layer

Developing plan for communication and collaboration by which the benefits of the healthcare IT will be demonstrated to the persons and to the physicians involved in the processes is necessary. Training is a significant component that suppose to encourage the patients to play a role in managing their own healthcare. The main idea is to create multi disciplinary teams that will be regularly consulted during the process of designing the systems, whether they are portals, mobile technologies or remote monitoring devices, in order to encourage patients to take an active role in managing their own health. The strategies should also take into consideration the local opinion on privacy, protection, security and confidentiality of the patients data to assure appropriate sharing and use of information for the benefit of the patients. The layer uses the advantages of the economy layer in terms of organization, but also serves to improve the economy policies taking into consideration a real life cases. Those experience and involvement of the different entities in creating policies also affects the layer that concerns the data by providing the policymakers with information of the properties that need to be preserved when developing such.

3.4 Data Layer

The use of structured data is necessary to enable an efficient leverage of it. The term structured data means that the data is stored in the same format and according to the specified standards by the policy makers in the first layer. The Data layer stands in between the users and the services. The users, whether they are patients or health institutions, need structured data to achieve interoperability from an information point of view and the services need standardized formats to enable a meaningful exchange and analysis of clinical data. The Data layer enables using Data Mining techniques for resource optimization in the prevention process as well as in the healing process. This layer is also beneficial for the patients self care since once they will have access to their personal information, the people will take greater responsibility for their own health.

3.5 Services Layer

All the healthcare applications for monitoring, decision or diagnostics, may have been developed in various technologies or by different standards. The Service layer should provide technical standards to which IT healthcare systems need to conform and use standardized data formats and common medical terminology in order to exchange the information between similar and dissimilar healthcare applications. A standardized communication platform would guarantee the accessibility and usability advantages to both patients and physicians [16]. CH can be enabled only by working with the service providers and ensuring technological capabilities.

3.6 Infrastructure Layer

Building the databases, getting the hardware right and understanding how to link the systems are all necessary actions for appropriate interaction of all layers, achieving interoperability and transitivity of services among each others.

4 Case Studies

By introducing our novel model we achieve new quality in two existing multi-functional systems. The first one, SIARS [7], is designed in multiple layers and consists of multiple services. When mapping SIARS, the system gains new quality by using the interoperability of our CHIL model. The second is a Bayesian

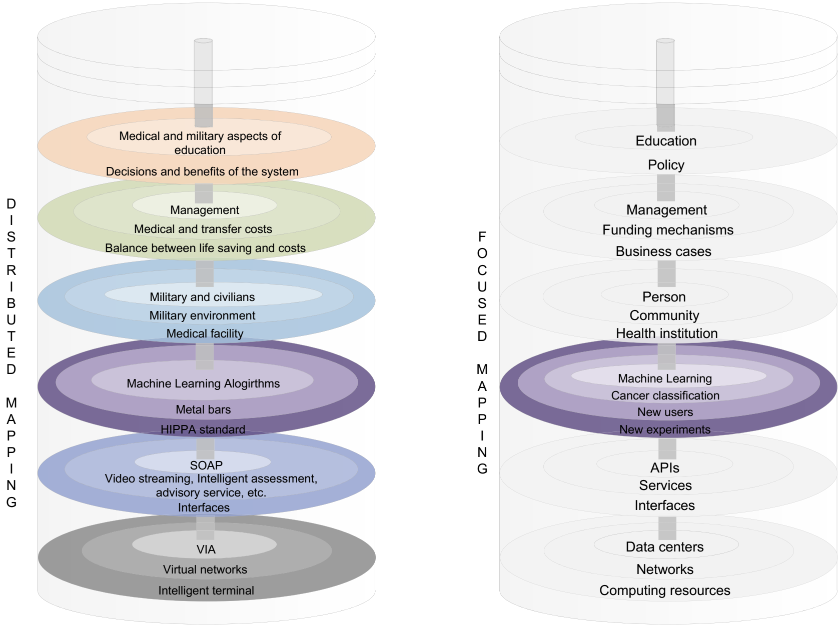

Fig. 2. Distributed vs Focused mapping

classification system that relies on gene expression data to perform diagnostics on the patients' health condition [8]. This classification system cannot be distributed on all the CHIL layers, instead it is focused only in the Data layer. However, the CHIL model still adds new quality by allowing the system to use its transitivity and easily face the issues as policies, education, its usage by the health institutions, costs for maintenance, services and infrastructure, and thus helping its upgrading to a stand-alone platform in a HC environment.

4.1 Distributed Mapping

This section presents an implementation concept of the cylindrical representation of CHIL as prove of concept for telemedical system (Smart I(eye) Advisory Rescue System SIARS) [7] development in military environment. SIARS works in two modes: on line, in the cloud infrastructure, consult the e-medical file of the injured and support on-line video stream with the medical specialist, or locally, off-line, with the Advisory Intelligent Module (AIM). The SIARS platform will be incorporated in the existing NATO projects and platforms, and will also be easily extensible with additional services. The distributed mapping of SIARS is presented in Fig. 2.

First layer for policy wraps up decisions for telemedical system development with its goals, objectives and outcomes that society will have after the system implementation. Additionally, the benefits from the system should be implemented in the policy layer. These elements are the basis for the initial phase and can be upgraded with additional elements. Education in SIARS can be considered from the following four aspects:

- Information technology (IT) aspects - knowledge that engineers have when the system is in development phase;
- Medical aspects - expertise that is necessary for proper definition of the system functionalities and user requirements;
- Military aspects - also necessary for appropriate development of SIARS, and
- End-user aspects - adequate training related to the final product.

The Economy aspect of SIARS is evident through the Management optimization when the wounded person is to be transfered to the nearest medical facility, since it requires usage of substantial technical items. CHIL enables to build a strong business case that will be the perfect balance between the life saving and the medical and transfer costs. Additionally, this layer directly communicates with the Data layer.

The users in the third layer encompass person, community and health institution. In our case we are following CHIL, but we are focused on the establishment of this concept in a military environment. Therefore, in order to have more robust and comprehensive SIARS development we can enhance the third layer of the CHIL model by adding another horizontal level - Environment. Users that are selected in SIARS development are military persons (soldiers, doctors and patients) and wounded civilians. In this case study soldiers (life savers) are users that can give first aid by using the SIARS and transfer the data to the medical facility. Doctors in medical facility can receive transferred data and prepare for further actions. Previously mentioned roles are users in the system.

Data layer in our cylindrical presentation encompass validity, authentication and security. In our case study we consider all three elements for SIARS development. Gathering and processing the data is done by ML tools, especially the knowledge engineering approach. We find authentication to be very sensitive element in a military surrounding. The identification of the military personnel is plain and simple because their data is already available in the system. The problem with authentication arises with civilians since their personal data is not previously available. For SIARS, we propose the authentication to follow HIPAA standard as a security rule. Considering the security of data, DDL triggers and DML triggers should be customized on appropriate level, thus each operation for changing certain data in the database will be caught and digital forensic can be applied.

In [7] authors show a model for telemedical information system for blood type analysis in a military environment based on Service Oriented Architecture (SOA). SOA based multi-tier approach provides legacy systems to be hooked up in a new infrastructure where new systems and legacy systems can communicate without complexity in communication protocol [17]. We followed the authors' [7] idea and based our case study on the SOA concept. The horizontal communication in CHIL indicates interoperability which means that the SIARS services written in different programming languages are capable to communicate. In this connotation, processing elements (web servers, sensors for collecting data, etc.) can create distributed environment for sharing information. SIARS will provide prototype platform with basic functionalities as services in the cloud (on-line) and local (off-line) modules that will be tested in real situations. The main novelties are the video-streaming of the injured person, advisory/learning service and intelligent assessment of the level of injury. The platform will be extensible providing basis for implementing additional telemedical services.

The proposed distributed application requires fast and reliable exchange of information across a network to synchronize operations and to share data. Traditional communication architectures do not provide the safe and secure communication links required by the proposed application. Therefore, we plan to realize a system as a stand-alone intelligent interactive terminal. In the first phase, we intend to develop a system for the local operation only and later we intend to connect the intelligent terminal to NATO telemedicine information system. Given the fact that we do not have access to the NATO standards, we plan to upgrade the system communications in the form of a popular Virtual Interface Architecture (VIA). The VIA specification describes a network architecture that provides userlevel data transfer. Hardware implementations of VIA support context management, queue management, and memory mapping functions in addition to standard network communication functions.

4.2 Focused Mapping

The methodology presented in [8] is based on statistical analysis of colorectal gene expression data and is applied in the Bayes' theorem for classification of colorectal tissues. The methodology can be implemented in the Data layer of the CHIL model, particularly in the processing and validity sub-layers of the model as presented in Fig. 2. The processing layer is fulfilled by the methodology itself that provides methods for statistical preprocessing and ML techniques for building the classification model. The model has been tested with new patients and the obtained results prove that the used techniques are valid, thus it also fits the validity sub-layer.

Given the horizontal opportunity for transitivity, the Bayesian classifier can be easily integrated in a tool for colorectal cancer analysis that will demand both the authentication and security sub-layers for authenticating new users and secure the patients confidentiality when performing new experiments.

The vertical possibility for transitivity and interoperability provides the advantage to develop the tool as a service and deploy it in a cloud infrastructure. This opportunity demands the activation of both the Service and the Infrastructure layers. Furthermore, the development of a user-friendly tool's interface demand an involvement of the physicians and clinicians that are part of the User layer. The maintenance of the tool in terms of cost-efficiency is a target of the Economy layer. The Policy layer is needed to provide appropriate training for its usage and teach on its benefits.

This implementation clearly presents the leverage of the structure of the CHIL model in terms of building blocks that can be a good indicator for upgrading and integrating a healthcare tool in the CH paradigm.

5 Conclusion and Future Work

This research examines the problem of incomplete CH models and proposes a novel model that solves the interoperability and transitivity issues reported in the literature. The introduced CHIL model, follows cylindric design that comprises different layers organized in sub-layers. Even though the design is elaborated in a hierarchical manner, it is flexible and allows communication between the layers without the necessity of consulting the neighboring layers first. Therefore, the actions triggered by any layer can affect the rest of the layers.

To test the ability of the CHIL design to implement any kind of medicine system in the CH paradigm, we analyze two types of existing systems developed in a different manner. The first case study analyze a distributed implementation of a telemedical advisory rescue system and the second case study exhibit a focused implementation of a methodology for classification of patients in a single layer of the model and its potential to use its leverage in terms of interoperability and transitivity to spread over the rest of the layers and obtain its distributed form.

In our future work we will upgrade the COHESY model, described in Sect. 2, by following our CHIL design. The goal is to achieve maximum utilization of its potential to collect, analyze and derive decisions on behalf of improving the health in the way defined [2] and thus confirm the validity of our approach.

Acknowledgment

This work was supported by TD COST Action TD1405 - "European Network for the Joint Evaluation of Connected Health Technologies" (ENJECT) and the NATO Science for Peace and Security Program Project ISEG.IAP.SFPP 984753.

References

1. Organization, W.H., et al.: www. who. int/bulletin/archives/80 (12) 981. pdf who definition of health. In: Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York. (1946) 19–22
2. Saracci, R.: The world health organisation needs to reconsider its definition of health. Bmj **314** (1997) 1409
3. Shukla, D., Patel, S.B., Sen, A.K.: A literature review in health informatics using data mining techniques. Int. J. Softw. Hardware Res. Eng. IJOURNALS (2014)
4. Wragge, Co: Connected health white paper (2014)

5. Accenture: Connected health: The drive to integrated healthcare delivery (2012)
6. Kovac, M.: E-health demystified: An e-government showcase. Computer **47** (2014) 34–42
7. Tasič, J.F., Bogdanova, A.M., Achkoski, J., Glavinov, A.: Service–oriented architecture model for blood type analysis (smart i (eye) advisory rescue system) in military environment. In: ICT Innovations 2013. Springer (2014) 149–156
8. Simjanoska, M., Madevska Bogdanova, A., Popeska, Z.: Bayesian posterior probability classification of colorectal cancer probed with affymetrix microarray technology. In: Information & Communication Technology Electronics & Microelectronics (MIPRO), 2013 36th International Convention on, IEEE (2013) 959–964
9. Trajkovik, V., Koceski, S., Vlahu-Gjorgievska, E., Kulev, I.: Collaborative health-care system (cohesy) model. mHealth Multidisciplinary Verticals (2014) 101
10. Trajkovik, V., Koceski, S., Vlahu-Gjorgievska, E., Kulev, I.: Evaluation of health care system model based on collaborative algorithms. In: Mobile Health. Springer (2015) 429–451
11. Jovanovik, M., Bogojeska, A., Trajanov, D., Kocarev, L.: Inferring cuisine-drug interactions using the linked data approach. Scientific reports **5** (2015)
12. Soni, J., Ansari, U., Sharma, D., Soni, S.: Predictive data mining for medical diagnosis: An overview of heart disease prediction. International Journal of Computer Applications **17** (2011) 43–48
13. Sullivan, L.M., et al.: Chronic disease data and analysis: Current state of the field. Journal of Modern Applied Statistical Methods **1** (2002) 32
14. Farran, B., Channanath, A.M., Behbehani, K., Thanaraj, T.A.: Predictive models to assess risk of type 2 diabetes, hypertension and comorbidity: machine-learning algorithms and validation using national health data from kuwaita cohort study. BMJ open **3** (2013) e002457
15. O'Grady, M.J., Capretta, J.C.: Health-care cost projections for diabetes and other chronic diseases: the current context and potential enhancements. Partnership to Fight Chronic Disease (2009)
16. Bellazzi, R., Montani, S., Riva, A., Stefanelli, M.: Web-based telemedicine systems for home-care: technical issues and experiences. Computer Methods and Programs in Biomedicine **64** (2001) 175–187
17. Achkoski, J., Trajkovik, V.: Service design and distributed system reliability in intelligence information system based on service-oriented architecture. In M. Ganzha, L. Maciaszek, M.P., ed.: Position Papers of the 2014 Federated Conference on Computer Science and Information Systems. Volume 3 of Annals of Computer Science and Information Systems., PTI (2014) 211–217