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ABSTRACT

The Electronic Health Record (EHR) refers to an electronically maintained, connectible, mass of pertinent, patient-related, healthcare information collected during one or many patient encounters. It constitutes patient demographic data, encounter notes, laboratory reports, prescription details, and past medical records, besides other medical data. The EHR in essence should facilitate the precise future diagnosis, treatment, and decision support processes of patient healthcare. Since EHR technology is a burgeoning science, many facets lie under-used or under-utilized. Its implementation is primarily confined to national pockets, managed by individual National Health Systems (NHS). True, universally interoperable, consolidated EHR schemes are still a thing for the future; a migratory patient may not have his national EHR available in distant territories. Further, global consolidation of related EHRs are still a distant dream. This paper articulates a unified, sound, precise, and secure methodology for achieving much-desired International Interoperability and inclusive efficiency in Ubiquitous, Universal, Consolidated Electronic Health Records, optimising the derived merits of this prime technology. Utilizing some popular EHR schemes as base models, such as Health Level 7's (HL7) Electronic Health Record Functional Model (EHR-FM) and similar systems, this overarching solution can be extrapolated to any ubiquitous EHR environment.

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Authors referred to HL7 and other such models. Authors proposed the model and defined the parameters that ascertain international interoperability. Paper is interesting and is a good effort. Authors are recommended to conduct a survey about their design. They may involve users of systems and record their requirements about international interoperability. This will let users develop a system that can be deployed and utilized in real time. Technical details provided are appreciable and paper is considered for publication with minor revisions.

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3/184

Interpolated International Interoperability and Inclusive Efficiency in Ubiquitous Electronic Health Records (EHRs)

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Abstract **- The *Electronic Health Record* (EHR) refers to an electronically maintained, connectible, mass of pertinent, patient-related, healthcare information collected during one or many patient encounters. It constitutes patient demographic data, encounter notes, laboratory reports, prescription details, and past medical records, besides other medical data. The EHR in essence should facilitate the precise future diagnosis, treatment, and decision support processes of patient healthcare. Since EHR technology is a *burgeoning science*, many facets lie *under-used* or *under-utilized*. Its implementation is primarily confined to *national pockets*, managed by individual *National Health Systems* (NHS). True, universally interoperable, consolidated EHR schemes are still a thing for the future; a *migratory* patient may not have his *national EHR* available in distant territories. Further, global consolidation of related EHRs are still a distant dream. This paper articulates a unified, sound, precise, and secure methodology for achieving much-desired *International Interoperability* and *inclusive efficiency* in *Ubiquitous, Universal, Consolidated Electronic Health Records*, optimising the derived merits of this prime technology. Utilizing some popular *EHR* schemes as base models, such as *Health Level 7's* (HL7) *Electronic Health Record Functional Model* (EHR-FM) and similar systems, this overarching solution can be extrapolated to any ubiquitous *EHR* environment.**

Index Terms **– Consolidated, Electronic Health Records, International Interoperability, Ubiquitous.**

1. INTRODUCTION

The *Electronic Health Record* (EHR) in its present-day manifestation is a dynamic, longitudinal, often localized data structure of valued, pertinent healthcare information. Data content covers patient encounters, patient, healthcare provider, and medication demographic data, treatments, laboratory reports, prescriptions, and medical history; infact efficient EHR implementations should embrace the entire spectrum of pertinent, captured healthcare data, enabling efficacious, prompt future diagnosis and treatment/cure of patients and diseases. The *Health Information Management System Society* (HIMSS) defines *EHRs* as follows **[1]**:

"*The Electronic Health Record (EHR) is a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting. Included in this information are patient demographics, progress notes, problems, medications. vital signs, past medical history, . immunizations, laboratory data, and radiology reports. The EHR automates and streamlines the clinician's workflow*".

In consequence of *EHR* interpolation in the *IT-driven* healthcare sector, many allied healthcare standards were instituted. For instance, *Health Level 7* (HL7) developed the *Electronic Health Record System Functional Model* (EHR-S FM) which "*provides a reference list of functions that may be present in an Electronic Health Record System (EHR-S). The function list is described from a user perspective with the intent to enable consistent expression of system functionality* " **[2]**. Functional profiles are created thereafter affording standardized descriptions of selected areas and settings. "*A Functional Profile is a selected set of functions that are applicable for a particular purpose, user, and care setting*" **[2]**. It is a pertinent subset of the complete function list in the *EHR-S FM*. Hence the functional model acts as really an overarching reference to the allied *EHR* system, which in turn manifests in the form of one or many functional profiles. Currently in release 2, the *EHR-S FM* is presently *International Organization for Standards* (ISO) and *American National Standards Institute* (ANSI) approved; its prime objectives being **[1][3]** :

- Improved Quality of Patient Care.
- Efficient Patients/Costs Monitoring.
- Filips to the Healthcare Industry.

4/74

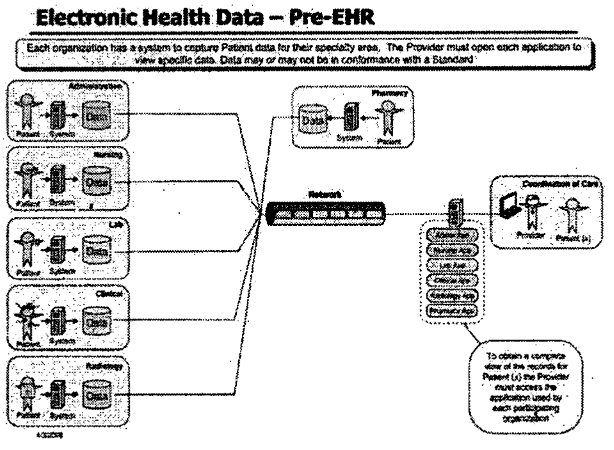
- Improved Documentation and System Audit Readiness.
- Interoperability.
- Safety/Security.
- Quality/Reliability.
- Efficiency/Effectiveness.
- Communication.

An *EHR* standard dictates the modalities for the exchange of vital, pertinent healthcare information and interoperability. It provides common language parameters for the design and development of *EHR* systems **[2]**. *Semantic Interoperability*, defined as the ability of two or more computer systems to exchange valued healthcare information with common understanding, is the principle perk accrued and the expectation of every *EHR* implementation. Present-day EHR systems however, are mainly institution-based and confined to national boundaries, managed by individual *National Health Systems* (NHS). Further, *EHR* technology is still a *burgeoning science*, with many facets and perspectives *under-utilised* and *under-used.* True, *universally interoperable* and *consolidated EHR* schemes pertaining to far-flung, related *EHRs* are still distant dream. In this study, we extended and enhanced the *EHR-S FM R2* (current version) utilizing the proposed *Unified DataAtom* (UDA) solution, affording overarched, universally efficient, creation, maintenance, and instantaneous access to *EHRs* anywhere in the world. Accordingly, this paper is organized as follows; Section II covers *UDA-driven EHR Structural Enhancement*, Section III presents the *Enhanced UDA-based EHR Development Methodology*, Section IV articulates the *Enhanced UDA-based EHR Model Formalism*, Section V compares conventional *EHR* models with the enhanced *UDA-based EHR* model, Section VI presents the enhanced *Functional List for International Interoperability*, and Section VII sums up with the *Conclusion* of the overall research findings.

II. UDA-DRIVEN STRUCTURAL EHR ENHANCEMENT

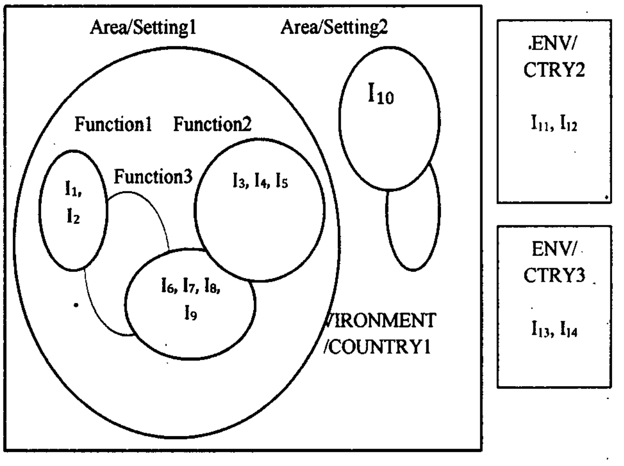
The pre-EHR contention involved the creation of electronic records for each area of patient care, eg., radiology, laboratory, pharmacy, or emergency. These records are *unintegrated*, and have their own *user log-ins* and *patient identification schemes.*

Fig. 1 : Electronic Health Data – Pre-EHR [1]



Each area-related subsystem may have been developed by different vendors using different languages and methods for user/patient identification and even access, lacking uniformity of operation across all silo systems (areas). Further, retrieval of a pertinent, encompassingly exhaustive electronic record would entail serial login to all sub-applications and aggregating allied patient record fragments **[1]**. Allied issues include unintegrated organization, inordinately lengthy access times, vocabulary variations across silos, and gross data duplication, incompatibility, and inconsistency. These issues are accentuated and exacerbated by the universal spread of pertinent electronic patient record fragments due to patient migration. Indeed the principle objective of this study and the associated crafted solution for enhanced *EHR* design and implementation, is to mitigate if not totally eliminate deleterious effects caused by poor current practices in electronic health record design.

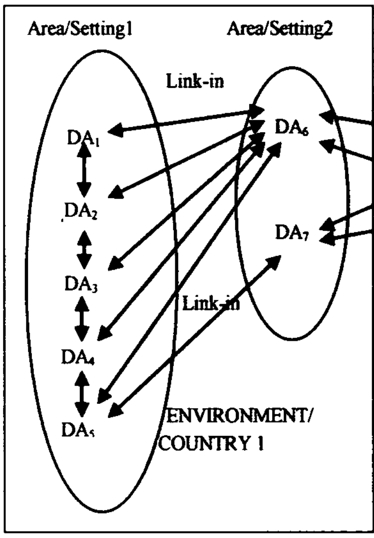
Fig. 2 : Conventional Electronic Health Record Model



I_x : *EHR Information/Data* Item, where x = Item Number

$ENV/CTRY_y$: Environment/Country, where y = ENV/CTRY Number

Fig. 3 : Enhanced *UDA-based* Electronic Health Record Model



↔ : Bi-directional inter-DataAtom Links
DA : DataAtom

We define a *DataAtom* as the semantically most minute, indivisible unit of data in the system. Captured mass data is decomposed and fragmented to semantically meaningful data *atoms*. The *Unified DataAtom* (UDA) topology imposes a bi-directional, all-connected lattice on the *cloud* of *DataAtoms* (also referred to as *DataAtom Schema* or *Stratum* herein).

III. ENHANCED UDA-BASED EHR MODEL FORMALISM

A. EHR-S FM R2 to UDA Transformation Formalism

Let F^{LP} be the *EHR-S FM R2* source functional list profile representation and U be the *UDA* target solution representation.Let T^{EHR} be the ***strict*** mapping transformation from F^{LP} to U preserving ***completeness***, ***accuracy***, and ***integrity*** of the functional list profile information. Further T^{EHR} satisfies the necessary condition of the mapping. The k constituent functions of F^{LP} (ie., elements, wrapper elements, attributes, values) are represented as F^{LP}_i (i = 1,2,3,4, ...,k). Since T^{EHR} signifies a strict mapping (precise functional list profile decomposition to target DataAtom stream), there is no change in the set of *mapped* elements during the transformation.

Let F denote the total set of all source data items contained in the given functional profile.

Then $F = \sum F^{LP}_1 + \sum F^{LP}_2 + \sum F^{LP}_3 + \sum F^{LP}_4 + \ldots\ldots\ldots\ldots\ldots + \sum F^{LP}_k$

If Ů denote the uniqueness function operating on a set.c

Then $ŮF = \{d_i, d_2, d_3, d_4, \ldots\ldots\ldots d_m\}$, the set of distinct data items, constituting the decomposed functional list profile.

By definition, the *UDA* representation spawns *DataAtoms* uniquely, ie., a *DataAtom* is stored only once in the particular stratum. If the target *DataAtom* stream is signified as

$U = \{u_1, u_2, u_3, u_4, \ldots\ldots\ldots u_m\} = \sum u_j \quad j=(1, 2, 3, 4, 5, \ldots, m)$

From the above, we have $ŮF \equiv U$, the two sets are identical.

Note : *Number of items*(F) ≠ *Number of items* (U). In fact

Number of items(F) > *Number of items* (U)

We prove that the mapping $T^{EHR} : F \rightarrow U$ denotes a *Complete Transformation*, meaning the result of the transformation T^{EHR} is a *necessary and sufficient* target *set* U in relation to the source set F. This would also satisfy the *necessary* condition for the $F \rightarrow U$ mapping.

By Definition :

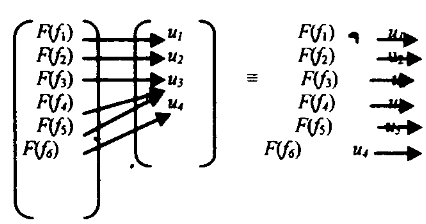
Injection of T^{EHR} : $\exists$ 1:1 mapping T^{EHR} of elements from domain F to codomain U $\forall f_i \in F \wedge \forall u_j \in U, \; i \in N \wedge j \in N$

Non-Injection of T^{EHR} : $\nexists$ 1:1 mapping T^{EHR} of elements from domain F to codomain U $\forall f_i \in F \wedge \forall u_j \in U, \; i \in N \wedge j \in N$
$\Rightarrow$ 1: n $\wedge$ n : 1 mappings are also possible

Surjection of T^{EHR} :
$\forall u_j \in U$ *there exists* $f_i \in F$ such that $T^{EHR}(f_i) = u_j$

In other words, $T : X \rightarrow U$ is an "*onto*" relationship.
Thus, the following mappings are established; by definition of T^{EHR}, F, U.

Fig. 4 : $T^{EHR} : F \rightarrow U$ Mapping Example



In this example, duplicate source data items $F(f_3)$, $F(f_4)$, $F(f_5)$ = u_3 target *DataAtom*. By definition, the source set can have duplicates, but the target set will only have unique elements. However, $ŮF \equiv U$ will always be true.

It can be established that :

T^{EHR} *is Non-Injective* : $\nexists$ 1:1 mapping T^{EHR} of elements from domain F to codomain U.
$\forall f_i \in F \wedge \forall u_j \in U, \; i \in N \wedge j \in N \; \{ i = 1, 2, 3, 4, 5, 6\}, \{ j = 1, 2, 3, 4 \}$
$\Rightarrow$ 1: n $\wedge$ n : 1 mappings also exist, eg., $F(f_5, f_4, f_3)$

T^{EHR} *is Surjective* : $\forall u_j \in U \ \ \exists f_i \in F$ such that $F(f_i) = u_j$

$\{ i = 1, 2, 3, 4, 5, 6\}, \{ j = 1, 2, 3, 4 \}$

In other words, $T^{EHR} : F \rightarrow U$ is an "*onto*" relationship.

Thus, every member u_j of target *UDA* co-domain *U is mapped onto* by at least one $f_i \in F$. There are no unmapped elements in either *F* or *U*.

Hence, $T^{EHR} : F \rightarrow U$ represents a ***Complete Transformation***.

IV. ENHANCED *UDA-BASED EHR* DEVELOPMENT METHODOLOGY

This section utilizes the *EHR-S FM R2* as the base *EHR* model for proposed enhancement; the methodology can however be seamlessly extrapolated to any ubiquitous *EHR* environment. The *EHR-S FM R2* consists of seven functional groups namely, *Overarching, Care Provision, Care Provision Support, Population Health Support, Administration Support, Record Infrastructure*, and *Trust Infrastructure* [2]. Each function list component consists of a *Function ID, Function Type, Function Name, Function Statement, Description, Conformance Criteria*, and *R1.1 Reference* (reference to previous version). The construction of the *EHR* model is *Area* (eg., Out Patient Division (OPD), Emergency, Ward, and so on) and *Setting* (Environment) specific. The steps to construction of a precision *EHR* model as given in [3] are :

- Define the area/setting and establish scope.
- Review the *EHR-S FM R2*, determine applicable functions, missing functions.
- Prioritise earmarked function list as *essential now, essential future, optional* as recommended in [3].
- Create a use-case scenario/case study for the particular area and setting. This would stipulate how the demarcated *EHR-S FM subspace* would apply to the said area/setting.
- Submit for HL7 review.

The enhanced *UDA-based EHR* development methodology completely supercedes its conventional *EHR counterpart* given above; it is *expanded, streamlined, value-added*, and reformulated. The essential phases are listed below.

- Define the area/setting and establish scope.
- Determine the complete listing of all informational *DataAtoms* pertinent/needed for *EHR* functionality in the particular area/setting. This should be completed vigorously using many or all of the techniques, viz, interviewing, questionnaires, observation, medical records. The subjects considered should be *medical practitioners, medical staff, administrative staff, patients, pertinent peer service provider staff and records*, and prevalent related *medical standards*. The listed *DataAtoms* should be environment and area/setting-specific informational content of precise context.
- A *Universal DataAtom Format Reference* (UDFR) guide should be maintained. This guide dictates the standardized, allowable, *DataAtom* types and their formats, and should be properly indexed for prompt, real-time access and use. In fact it is the super-schema of all *DataAtom* types and formats contained in any interoperable *EHR* system. This encyclopaedic *DataAtom* reference is maintained periodically and kept up-to-date using proper *Harmonizing* procedures. Low-level, uniform analysis and design interoperability across all projects, systems, and even geographical regions is ensured by the *UDFR*. Indeed, it is equivalent to a *DataAtom-oriented Reference Information Model* (RIM).
- Determine applicable functions, missing functions. Meaningfully map the generated *DataAtoms* to pertinent functions, if necessary. This is only to aid in the subsequent modularized system development process. Encircle and perform function-wise sub-division of the specific *area-related DataAtom stratum/schema*. The resulting system of *sub-strata* may have some overlap; indicating the sharing of *DataAtoms* amongst overlapping functions. In addition, the intrinsic *all-around-connectivity* of individual *DataAtoms* connotes higher-level, seamless *Functional Interoperability* amongst all functions (sub-strata). Hitherto unmapped regions represent gaps in the *EHR-S FM* functional list, and these *DataAtoms* are bundled appropriately into new functions (sub-strata) with fitting *nomenclature*. It is recommended to strictly adhere to the functional nomenclature as presented in the *EHR-S FM R2* documentation, or the pertinent *EHR* system documentation. This would institute *interoperability* at all levels, from the *low-level, UDA-enacted analysis, design*, and *sub-functional DataAtom interoperability*, to higher *functional interoperability*.
- Alternatively, the spawned area/setting-related *DataAtom cloud* can be bundled as one function, or a different set/number of functions(sub-strata) according to project need or stakeholder requirement, deviating from the guidelines enunciated in the base *EHR* documentation. This flexibility is afforded by the proposed *UDA-based EHR development methodology*.

7/24

- Insert appropriate *DataAtom Demarcators* to the *DataAtom schema* in order to *inject* structure and stratification to the burgeoning *DataAtom Cloud-oriented EHR* (it is not longitudinal anymore). The stratification could be based on areas/settings, environments, geographical regions, or even conceptual functionality, or a mix. Essentially, stratification is performed in order to ensure ease of *DataAtom spawning* (*creation*, *writing*), *linkage*, *access*, and *reading*.
- Prioritise encircled functions as *essential now*, *essential future*, *optional* as before **[3]**. However, this would now depend on the *synergistic grouping priority* of the contained *DataAtom cloud* in the said function (sub-stratum). Threshold priority weightages can be utilized for this determination.
- Create a use-case scenario/case study for the particular area and setting. This would stipulate how the demarcated *EHR space* would apply to the said area/setting.
- Review and finalise through stakeholder consensus.
- **Note** : Patient demographic data would remain relatively constant, over a period of time. But related encounter notes, laboratory reports, prescription details, and past medical records would grow over time, and thus their allied *DataAtom* sub-clusters would also *distend* commensurately.

V. CONVENTIONAL *EHR* VERSUS THE ENHANCED *UDA-BASED EHR* MODEL

The table below provides a comparison of the conventional *EHR model* (*EHR-S FM R2* in this case) with the proposed enhanced *UDA-based EHR* model, revealing merits of the proposed solution.

TABLE I
CONVENTIONAL EHR-S FM R2 VERSUS PROPOSED UDA-BASED EHR MODEL

Index	Functionality/ Feature	Regular *EHR*	Enhanced *UDA-based EHR* (Enhancement /Improvement)
1	Functional Profiles	Important	Finer Grained *DataAtom* Profiling, - True low-level interoperability **(POSITIVE)**
2	Profile Traceability	Possible	Finer Grained *DataAtom* Profiling - True low-level *DataAtom Traceability* **(POSITIVE)**
3	Common Language, Uniform Vocabulary	Low	High, Uniform **(POSITIVE)**
4	Functional Model Structure and Extensibility	Possible	Higher Degree – Finer Grained **(POSITIVE)**
5	Priorities	Functional-level	DataAtom Level **(POSITIVE)**
6	Extensibility	Possible	Greater, Finer-Grained, possible **(POSITIVE)**
7	Improved Quality of Patient Care	Yes, with use of EHR	Improved, higher quality, with *International Interoperability* (II) **(POSITIVE)**
8	Efficient Patients/Costs Monitoring	Yes, with use of EHR	Improved, higher quality, with ***II*** **(POSITIVE)**
9	Filips to the Healthcare Industry	Yes, with use of EHR	Numerous, Higher Number **(POSITIVE)**
10	Improved Documentation and System Audit Readiness	Yes, with use of EHR	Improved, higher quality, with ***II*** **(POSITIVE)**
11	Interoperability	Yes, limited within bounds.	Truly global ***II*** possible **(POSITIVE)**
12	Safety/ Security	Yes	Yes, finer-grained *DataAtom-level* **(POSITIVE)**
13	Quality/ Reliability	Yes, with use of EHR	Improved, higher quality, finer-grained **(POSITIVE)**
14	Efficiency/ Effectiveness	Yes, with use of EHR	Improved, higher quality, with fine-grained, faster, data control and access **(POSITIVE)**
15	Communication	Improved, with use of EHR	Improved, higher quality, with finer-grained, true ***II*** **(POSITIVE)**
16	Unintegrated Organization	Yes	Organized and Structured **(POSITIVE)**
17	Access Time	Good	Super-Fast,, Single-Step *DataAtom* Access **(POSITIVE)**
18	Data Duplication	Yes	Minimal, almost Nil **(POSITIVE)**
19	Data Incompatibility/ Inconsistency	Yes	Minimal, almost Nil. Each datum stored only once. **(POSITIVE)**
20	Simplicity, Ease of Applicability	Yes	Much Enhanced **(POSITIVE)**

The *EHR* approach for modelling electronic health information efficiently supercedes conventional silo-based functional systems, sanctioning its present use in the *IT-driven* healthcare sector. But, the proposed enhanced *UDA-based EHR model* exhibits a significant (20/20 x 100) = 100% improvement and enhancement over its extolled regular *EHR* counterpart as shown above, categorically endorsing its future induction into the *IT-based* healthcare industry.

8/74

VI. FUNCTIONAL LIST FOR IMPROVED INTERNATIONAL INTEROPERABILITY

The primary model for this research, the *EHR-S FM R2* is based upon a *Function List*. This list defines overall system functionality facilitating stakeholder discussion and consensus. Each function is defined using a *principle parameter set*, ie., *Function ID*, *Function Type*, *Function Name*, *Function Statement*, *Description*, and *Conformance Criteria* [2]. R2 also consists of seven sections namely *Overarching*, *Care Provision*, *Care Provision Support*, *Population Health Support*, *Administration Support*, *Record Infrastructure*, and *Trust Infrastructure*. The proposed *UDA* solution will not affect the *EHR-S FM R2* functional descriptions per se. However, since this enhanced solution is overarching and convergent towards true *International Interoperability*, fittingly an additional section for *International Interoperability* has been included. Note that these functions only cover the *internationalization* aspect, such as global registration of participating *Service Providers* for international visibility and access, the *request* and *render* processes for the *consolidated EHR*, and the calling of the *Link-In* process for *EHR consolidation*. Hence, this implementation requires that all query-reference objects such as *service providers*, *medical practitioners*, *patients*, *diseases*, *treatments*, and *medications*, be registered at the point of initial creation, with relevant demographic information, *and* a *globally applicable-and-accessible Object ID* (OID). The associated functional list for the new *International Interoperability* section is tabulated below.

TABLE II
PROPOSED FUNCTIONAL LIST FOR INTERNATIONAL INTEROPERABILITY

ID (Type)	Name (Statement)	Description	Conformance Criteria
II.1 **(H)**	Manage *International Interoperability*. **(Manage the true universal exchange of electronic health information).**	The solicitation and authorized, secured exchange of pertinent electronic health records relating to service providers, medical practitioners, patients, diseases, and medication. Covers patient medical history, encounter records, and prescriptions.	The system should provide the ability to manage true authorized, international, electronic exchange with common understanding of health records of service providers, medical practitioners, patients, diseases, treatments, and medications.
II.1.1 **(P)**	Provide Universal Access for *Continent*. **(Formulate *Continent*-related information to facilitate true universal exchange of electronic health information).**	The *Continent*-specific information such as *Universal-Continent-ID* for use in *messages*, *database/ cloud* querying, and *OIDs*,to uniquely filter and request or access required healthcare information from destination *service provider / universal cloud*.	The system should provide the ability to create, store, and manage pertinent *Continent-related* demographic information to facilitate true authorized, *international*, electronic exchange with common understanding of health records of service providers, medical practitioners, patients, diseases, treatments, and medications.
II.1.1.1 **(P)**	Provide Universal Access for *Country*. **(Formulate *Country*-related information to facilitate true universal exchange of electronic health information).**	The *Country*-specific information such as *Universal-Country -ID* for use in *messages*, *database/ cloud* querying, and *OIDs*,to uniquely filter and request or access required healthcare information from destination *service provider / universal cloud*.	The system should provide the ability to create, store, and manage pertinent *Country –related* demographic information to facilitate true authorized, *international*, electronic exchange with common understanding of health records of service providers, medical practitioners, patients, diseases, treatments, and medications.
II.1.1.1.1 **(P)**	Provide Universal Access for *Service Provider*. **(Register locally the demographic and other universal coordinates of a new *Service Provider*).**	All participating globally spread *Service Providers* should register locally their pertinent demographic and other information such as *universal OID*.	The system should provide the ability to register and maintain new *Service Provider* information in the EHR-provider network cloud, or universally-visible *EHR-provider* database.
II.1.2 **(P)**	Universal Access to *LocalDatabase/ Universal Cloud*. **(Formulate *database/ universal cloud-related* information to facilitate true, direct universal access or exchange of electronic health information amongst**	All data storage resources such as *local databases* or *universal cloud* resources should be globally accessible to all participating stakeholders, either through *messaging/ query requests* or *direct access*	The system should provide the ability to register and maintain all data resources, either the *local databases* or the *universal EHR-network cloud*. These resources should be globally accessible to all

	participating service providers and other stakeholders).	(especially in the case of *universal cloud*).	participating stakeholders, either through *messaging/ query requests* or *direct access* (especially in the case of *universal cloud*).
II.1.1.1.1 .1 **(C)**	Provide Universal Access for *Medical Practitioner*. **(Register locally the demographic and other universal coordinates of a new *Medical Practitioner*).**	All participating globally spread *Medical Practitioners* should register locally their pertinent demographic and other information such as *universal OID*.	The system should provide the ability to register the new *Medical Practitioner* information in the EHR-provider network cloud, or universally-visible EHR-provider database.
II.1.1.1.1 .2 **(C)**	Provide Universal Access for *Patient*. **(Register locally the demographic and other universal coordinates of a new *Patient*).**	All participating globally spread *Patients* should register locally their pertinent demographic and other information such as *universal OID*.	The system should provide the ability to register the new *Patient* information in the EHR-provider network cloud, or universally-visible EHR-provider database.
II.1.3 **(P)**	Provide Universal Access for *Disease*. **(Register locally the demographic and other universal coordinates of a new *Disease*).**	All *Diseases* should be registered with other information such as *universal OID*.	The system should provide the ability to register the new *Disease* information in the EHR-provider network cloud, or universally-visible EHR-provider database.
II.1.4 **(P)**	Provide Universal Access for *Treatment*. **(Register locally the demographic and other universal coordinates of a new *Treatment*).**	All *Treatments* should be registered with other information such as *universal OID*.	The system should provide the ability to register the new *Treatment* information in the EHR-provider network cloud, or universally-visible EHR-provider database.
II.1.5 **(P)**	Provide Universal Access for *Medication*. **(Register locally the demographic and other universal coordinates of a new *Medication*).**	All *Medications* should be registered with other information such as *universal OID*.	The system should provide the ability to register the new *Medication* information in the EHR-provider network cloud, or in universally-

			visible EHR-provider database.
II.1.6 **(P)**	Provide Universal Access to *Consolidated EHR*. **(Provide universal access to the *consolidated universal EHR* from any participating *stakeholder login* or *location*).**	All authorized, participating stakeholders should have access to the *consolidated universal EHR* on demand, from the globally-spread EHR segments in *local databases*, or from the *universal EHR-network cloud*.	The system should provide the ability to access the *consolidated universal EHR* on demand, from the globally-spread EHR segments in *local databases*, or from the *universal EHR-network cloud*.
II.1.6.1 **(C)**	Access Universal *Patient* EHR **(Access the universal *Patient* EHR based on the supplied universal *Patient OID*, from any participating location/login).**	Apply the *Link-In* process intrinsically to consolidate spread-out EHR fragments, based on supplied universal *Patient OID*, from any participating location/login. Automated access possible according to predetermined *agreement*.	The system should provide the ability to access the complete, consolidated, universal, *Patient* EHR, based on the universal *Patient OID*, from any participating location/login. The relevant EHR fragments could be in the EHR-provider network cloud, or in universally-visible-and-accessible EHR-provider databases worldwide. The latter situation would entail specific *Request* and *Render* subprocesses between source and destination.
II.1.6.2 **(C)**	Access Universal *Disease* EHR. **(Access the universal *Disease* EHR based on the supplied universal *Disease OID*, from any participating location/login).**	Apply the *Link-In* process intrinsically to consolidate spread-out EHR fragments, based on supplied universal *Disease OID*, from any participating location/login. Automated access possible according to predetermined *agreement*.	The system should provide the ability to access the complete, consolidated, universal, *Disease* EHR, based on the universal *Disease OID*, from any participating location/login. The relevant EHR fragments could be in the EHR-provider network cloud, or in universally-visible-and-accessible EHR-provider databases

10/74

			worldwide. The latter situation would entail specific *Request* and *Render* subprocesses between source and destination.
II.1.6.3 **(C)**	Access Universal *Treatment* EHR. **(Access the universal *Treatment* EHR based on the supplied universal *Treatment* OID, from any participating location/login).**	Apply the *Link-In* process intrinsically to consolidate spread-out EHR fragments, based on supplied universal *Treatment OID*, from any participating location/login. Automated access possible according to predetermined *agreement*.	The system should provide the ability to access the complete, consolidated, universal, *Treatment* EHR, based on the universal *Treatment OID*, from any participating location/login. The relevant EHR fragments could be in the EHR-provider network cloud, or in universally-visible-and-accessible EHR-provider databases worldwide. The latter situation would entail specific *Request* and *Render* subprocesses between source and destination.
II.1.6.4 **(C)**	Access Universal *Medication* EHR **(Access the universal *Medication* EHR based on the supplied universal *Medication OID*, from any participating location/login).**	Apply the *Link-In* process intrinsically to consolidate spread-out EHR fragments, based on supplied universal *Medication OID*, from any participating location/login. Automated access possible according to predetermined *agreement*.	The system should provide the ability to access the complete, consolidated, universal, *Medication* EHR, based on the universal *Medication OID*, from any participating location/login. The relevant EHR fragments could be in the EHR-provider network cloud, or in universally-visible-and-accessible EHR-provider databases worldwide. The latter situation would entail specific *Request* and *Render* subprocesses between source and destination.
II.1.6.5 **(C)** and beyond.	Access any other *DataAtom-based* EHR. **(Similar to Above)**	Similar to Above	Similar to Above

Listed above is a subset of the complete functional list pertaining to *International Interoperability*. It is presumed that all initial data entry is performed at the respective locations of initial occurrence, and the *UDA-based* enhanced *EHR* is *housed* in the *universal EHR-provider* network cloud, or in *universally-visible-and-accessible EHR-provider* databases worldwide. The latter arrangement would entail explicit *Request* and *Render* messaging between source and destination. Hence, given that the *UDA-driven EHR* is already in production, this new section focuses only on the *universal interoperability* aspects of its operation.

VII. CONCLUSION

This research studied in depth the development and use of *Electronic Health Records* (EHR) in the global healthcare industry. In particular, it was ascertained that present practice dictated the *stifled* use of *EHRs*, due to the *unfledged* state of related technology. Many facets and perpectives of *EHRs* lie *under-utilised* and *under-used. EHR* creation, maintenance, and use is confined to convenient healthcare-provider and national boundaries. Little or no scalability to *realms universal* exist, nor *pathways* for *on-the-fly* global *EHR* consolidation, causing grave hindrance to our principle goal of true *International Interoperability*. Further, far-flung, unorganized, mushrooming clusters of *EHR* implementations infuse and breed alarming inefficiencies into the total network; *unintegrated organization*, *inordinately-lengthy access times*, *vocabulary variations*, and *gross data duplication*, *incompatibility*, and *inconsistency*. These ricochet on other performance criteria such as *Safety and Security*, *Quality and Reliability*, and *Efficiency and Effectiveness*. This paper propounded a unified, sound, precise, and secure methodology to achieve efficient *International Interoperability* amongst all participating healthcare providers. It utilized the proposed *Unified DataAtom* (UDA) modelling representation to good effect, actualizing an *EHR* structural enhancement and an improved development methodology, commensurate with our requirements. A revised and enhanced functional list for much-sought *International Interoperability* is also presented.

The primary *EHR* base model used for this study was *HL7's EHR-FM*, amongst others. *EHR-FM* was a worthy choice since *HL7* is the predominant global healthcare standard in operation today. However, the proposed solution is *overarching*, *ubiquitous*, *seamlessly scalable*, and *versatile* and can be easily extrapolated to any

EHR-based environment, a true endorsement of its efficacy and the embedded core *UDA* technology.

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12/74