On Modelling Digital Healthcare Ecosystems and their Knowledge Management

(Completed Research Paper)

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Abstract

The Human Anatomy, Physiology and Psychology Integrated Egghead Relationships (HAPPIER) are embedded domains of a human ecosystem. In the digital ecosystem perspective, the idiom “Integrated-Egghead-Relationships” describes composite domains with encapsulation of multiple data attribute dimensions. The increase in physiological and psychological disorders among the mass population in periodic and geographic dimensions has reported an outburst of volumes and varieties of data in healthcare ecosystems. The data heterogeneity and multidimensionality are other challenges constraining the data integration process, at times disconnecting patients and medical practitioners. Knowledge-based data models are needed to manage unstructured cognitive healthcare Big Data. The purpose of the research is to build a framework and integrate multilayered models in multidimensional warehouse repository. The integrated framework can engage multiple scopes of HAPPIER and collaborate with human cognitive anatomy and physiological data events in large-scale depositories. The repositories can bring values in new knowledge domains, making healthcare projects operationally successful.

Keywords

HAPPIER, Big Data, Multidimensional data modelling, Digital Healthcare, Knowledge Management.

Introduction

The ecosystems involving the human body, physiology and psychology with which we survive, have connections (Miller and Han 2001). The coexistence of domains and systems is the motivation of the research. The connections are in the form of nested data relationships, and each link is influenced by the other in different spatial-temporal dimensions. For example, when the human body is pristine, it is more likely to be healthier, functionally fit, psychologically conscious and alert. But the environments, in which the humans live, the conditions can change their physiology and psychology rapidly, affecting the anatomy of the human body. We term the phenomena as system connectivity and embeddedness of a human ecosystem. In the current research, using data constructs, models and methodologies, the importance of connectivity between several ecosystems is emphasized by Human Anatomy, Physiology and Psychology with Integrated Egghead Relationships (HAPPIER). The focus of this research is to build and analyze data relationships between different contexts of HAPPIER through Information System (IS) tools and technologies (Miller and Han 2001). Various articulations described in the IS development are added tools of ecosystem descriptions, manifesting the connectivity and integration processes (Coronel et al. 2011). Large size healthcare data are used to collaborate and link ecosystems in multiple contexts. However, the data relationships are contextualized, as appropriately interpretable in a human body with spatial attribute dimensions. We choose different ranges of data instances in diverse ecosystems to analyze the inherent interconnectivity in which each domain’s dependence agrees to concepts of the specification of conceptualization, inheritance and polymorphism (Coronel et al. 2011). For example, a domain model created for HAPPIER contexts inherits from coexistent systems, which can guide the healthcare investigation in complex data systems.

Literature Review and Research Gaps
We carry out a literature survey to explore the current research gaps. Neittraanmaki and Galeieva (2016) focus on efficient method and platform-centric system tool development for healthcare ecosystem management. They demonstrate the implementation with case experiments done for Finnish corporations and policy planners. Janjua et al. (2009) deal with healthcare standards and technologies to address the information access challenges and sharing knowledge from heterogeneous healthcare ecosystems. Benedict and Schlieter (2015) provide general guidelines for model design and implementation in eHealth Ecosystem projects. Kotla and Jain (2018) offer new insights for service providers and healthcare services. They describe a healthcare provider framework with big data, cloud computing and analytics tools. Iyawa et al. (2016) examine the existing literature on digital health innovation ecosystems.

Mantzana et al. (2006) emphasize the IS research in healthcare including various actors involved in the adoption process. LeRouge et al. (2007) highlight the strategic necessity of the IT tools and Technologies in the healthcare sectors. Hovenga and Sermeus (2002) describe healthcare related data with various terminologies used in different healthcare systems. Lim (2012) provides several fundamentals of health management information systems including their design, development and implementation of patient records in clinical scenarios including health insurance and fund management issues and challenges. Malliarou (2009) describes the Nursing Information System (NIS) as “a part of a health care information system that deals with nursing aspects, particularly the maintenance of the nursing record in clinics. Various issues and challenges pertinent to nursing healthcare data-bases are discussed. Grice (2018) discusses digital health implementations in the Australian contexts with new healthcare opportunities for the ageing population. Shah et al. (2019) describe the impacts of digital health on the safety and quality of healthcare. Nimmagadda et al. (2008) articulate new tools and technologies in various application domains. Lacasta et al. (2010) provide ontology solutions for designing and managing multiple practical applications. Hendry and Friedman (2008) describe the design aspects of IS practice and pedagogical approach and describes eight design perspectives including readings, key questions, and activities, concluding an interplay between theory and practice. Shah et al. (2019) review the literature on new insights and emerging directions of health informatics.

A disconnect is observed between patients and the medical staff. A conceptual framework can bring practitioners, professionals and academics in the digital domain together to address the challenges. The healthcare ecosystems typically possess heterogeneous and unstructured data with rapidly changing entities and dimensions within diverse domains. A holistic data modelling is lacking to explore the connectivity in diverse domains and systems. In addition to systematic mapping and modelling, documentation, data reconciliation and storage need utmost attention.

**The HAPPIER in Healthcare Management**

The purpose of this research is to articulate a digital healthcare ecosystem with various data entities and or dimensions associated with the human body that includes its functions and disorders. The structuring done in a metadata scale is factual in digital healthcare ecosystem representation, in which an opportunity exists to explore and model several data relationships in multiple domains. An articulated framework can collaborate the domain ontologies that describe various data relationships among the human anatomy, physiology and psychology dimensions (Nimmagadda et al. 2008; Nimmagadda et al. 2016). Ontology-based data warehousing and mining are needed to serve the purpose of managing the ecology of the human body, mitigating the diseases for drug prescription management (Cacioppo and Tassinary 1990; Fabiani 2012). We examine various healthcare related hierarchical and relational ontologies, demonstrating the study of human behavioural and social disorder data patterns in diverse knowledge domains. The HAPPIER events are echoed in the data artefacts including the behavioural and psychological fact instances occurred in spatial-temporal dimensions. In this research, we explore the impacts of human anatomy and physiology on psychological patterns, replicating them through Big Data guided information systems (Debortoli et al. 2014). The clinical researchers often interpret the concept of connectivity between interrelated disciplines such as psychology, psychiatry and public-health-related contexts through molecular biology, botany, zoology and ecology associated entities (Hadzie and Chang 2005).

Further, the relationships interpreted at different levels of stress and physical wellbeing are attributed to physiology-psychology models (Debortoli et al. 2014). In stressful conditions, the behavioural and physical actions can change, thus affecting the physiology and psychology, impacting their connectivity. Stress-related events also affect human anatomy (Carlson 2013). In addition, the activities related to physiological psychology that occurs in behavioral neurosciences are due to biological psychology (Carlson 2008). They cover the facts of human behavior, which is connected to the brain, one of the organs of the human body. Besides, physiological psychology relates to responses of the human body or interpretation of its associated behavioral actions. The response events attributable in composite data schemas can generate conceptualized attributes to linkup data events of brain cells, structures, components and chemical interactions. The psychology, as a part of the composite schema, exhibits sleep, emotions, ingestion, and senses, reproductive behavior including learning/memory, communication and neurological disorder attribute events, actionable by different physiological functions. Thus, the psychology entity, a branch of the
nervous system, intertwines with features of the human body and its structure. Such investigation in the context of **HAPPIER** is a description of connecting interrelated domains and systems through data relationships interpreted with exercise-physiology facts instances, routinely acquired from gymnasiums in periodic dimensions. We investigate the design aspects of **HAPPIER** contextualizing healthcare issues, which were not dealt with by previous healthcare researchers (Fabiani 2012). Various concepts, such as **HAPPIER**, Big Data, Multidimensional Data Modelling, Digital Healthcare, Knowledge Management and Data Mining are defined at appropriate places in the following sections.

**Research Questions and Objectives**

The introduction and literature surveys motivate us to draw research questions and objectives. Perceiving knowledge of embedded ecosystems in different geographic and periodic intervals is significant research in diverse ecosystem scenarios. Bringing the data together and sharing the processed data among several geographic dimensions are challenging. To date, there has been a limited investigation done on the exploration of data volumes and types of data sources existing in many healthcare applications (Shah et al. 2019). In such composites embedded systems, the data volumes at times are difficult to itemize, because of poorly scalable attributes. The adversity crops up while managing data volumes by traditional database management approaches. Besides, we realize that the massive stores of unstructured ecosystems’ data that hide useful information are inadequately documented. We propose new approaches for managing the embedded systems, where the systems are coexistent. If attribute dimensions get distracted in one system, others closely associated with them also get affected, implying that all the entities and dimensions are inherently interconnected and embedded. Based on the research problem statement, the following research questions have been framed:

1. Why do we design **HAPPIER** contexts for Digital Healthcare Systems?
2. How do we resolve **HAPPIER** settings in the integrated framework?
3. How do we implement the framework to bring out the information value?
4. Who are the beneficiaries of the healthcare ecosystem services?

**Research Significance, Motivation and Contribution**

The relevance of the study is described in this section. We intend to relate **HAPPIER** contexts and examine their effects on different ailments. In the data management perspective, the data held by embedded systems are unstructured in various domains, complicating the data integration and connectivity processes. The domain experts and healthcare researchers involved in the Big Data projects need holistic approaches for managing the data-centric ecosystems (Cleary et al. 2012; Schermann et al. 2014). The data models deduced in domain ontologies are flexible and adaptable to explore the connectivity – accommodating future changes that may occur in the embedded healthcare contexts (Hadzic and Chang 2005). Whether the objective of ecosystem data analytics is technical or business nature; the way forward is on building meta-knowledge in different spatial-temporal dimensions. Whether the objective of ecosystem data analytics is technical or business nature; the way forward is on building meta-knowledge in different spatial-temporal dimensions. Whether the objective of ecosystem data analytics is technical or business nature; the way forward is on building meta-knowledge in different spatial-temporal dimensions minimizing the ambiguity involved in the interpretation of a single digital ecosystem (Jerko and Nes 2011). Our motivation is on developing Information System approaches and managing unstructured data sources when two or more systems coexist, and their merge in the integration process arises. The proposed IS methodology realizes the human ecosystem issues, more broadly the **HAPPIER** contextual attributes, including their value chains extendable in many other domains and systems (Cacioppo and Tassinary 1990). The heterogeneity and multidimensionality of Big Data associated information systems can significantly change the perception of healthcare ecosystems.

**Development of Framework and its Components**

We have described the generic digital ecosystems in the healthcare domain. We have highlighted the “knowledge management” that can be conceptualized in systems’ connectivity and implemented from the holistic framework. To address the research questions 1 and 2, various artefacts in the form of data models are designed to accommodate and interconnect various tasks and activities of **HAPPIER** in the framework. IS research is a major motivation, driving the framework, in which data acquisition, processing, interpretation and delivery of new knowledge to the IS researchers are key components. The methodology demonstrates the rigor on data science of human anatomy (Miller and Han 2001; Schermann et al. 2014). To discern the influence of physiology and psychology on human anatomy, we present a Big Data guided integrated framework with a focus on modelling spatial-temporal data dimensions and their instances. The spatial-temporal controlled Big Data have motivated us to develop healthcare IS research paradigms on a global scale. Empirical–observational research is adopted including data modelling, model integration, healthcare ecosystem analytics and knowledge management. Several such **HAPPIER** scopes that arise with interconnected nests and their associated digital data are interpreted in the following sections.

**Human anatomy ecosystems:** To establish the connectivity between nested events of **HAPPIER**, we propose the simulation of anatomical models with an ontology-based data warehousing approach (Coronel et al. 2011; Hadzic
and Chang 2005) that can simplify the human anatomical representation in a knowledge-based interpretation. Data about anatomy and their types are dimensions of the human body. We use “dimensions” in the multidimensional data structuring process. For example, we depict ontologies for building data relationships among anatomy elements skeletal, digestive, muscular, lymphatic, endocrine, nervous, cardiovascular, male reproductive, female reproductive and urinary, interpreted as dimensions. The integrated warehouse schema searches for connections from common attributes of human physiology and psychology realms and brings them together in an anatomical metadata structure, which is described in the following sections.

**Human physiology ecosystems:** The functions of the parts of the human body are interpreted as physiological dimensions and how various diseases impact the functions in different environmental conditions, under which the human body can sustain. We consider physiology as an entity that is composed of sensory, pains, injury, exercise and heart rate attributes, to connect to pertinent common attributes of the human anatomy and psychology (Fabiani 2012; Jerko and Nes 2011). Pedaling machines existing in gymnasiums are good sources of data, because of exercise-physiology activities. The physio-exercise activities and associated events interpreted in human anatomy and psychology entities explore connections and even interrelationships of HAPPIER contexts. So, we choose to acquire data from pedaling machines, with which physio-exercise activities taken place in periodic dimensions are continuously monitored for five years. We construct H – D – R – C – T – L structure, with H “HeartRate”, D “Distance (human body undergone physio-exercise in distance)”, R “RPM (revolutions per minute, speed of machine or movement of the body)”, C “Calories (spent)”, and T “(Time spent in physio-exercise)” and L “Level (physio-exercise level set)” dimensions to accommodate in dimensional models. Each attribute dimension described in physiology modelling does physically exist. The spinal cords, heart-rate, pain management, brain, skin system, insulin management, tissue, muscles and building cells are different dimensions while managing the exercise-physiological activities. The sensitiveness, pain and injury management, healing and tissue management are other attributes logically used in the physiological dimension modelling. The physiological activity linked to attribute dimensions is modelled in different data schemas that connect to human anatomy and psychology entities through their common attributes.

**Human psychology ecosystems:** The tense, emotion, greedy, behavioral, confidence, happiness, sadness and psychological events affect the psychological attribute dimensions. The human psychophysiology (Carlson 2013; Carlson 2008) is a conceptualized composite entity deduced from physiology and psychology contexts. The abnormalities noticed in human behavioral neuroscience, cognitive neuroscience, cross-cultural domains can collaborate with attribute dimensions and their corresponding realms of physiology and human anatomy entities. For this purpose, varied attribute dimensions in diverse spheres of systems are conceptualized to adapt and shelter in hundreds of schemas and integrated framework (Shanks et al. 2004). We describe several components of warehouse framework in the following sections:

**Domain modelling:** The domain model is a representation of conceptualized and contextualized vocabularies and semantic relationships between attributes of the embedded healthcare systems. Multiple domains, their attribute dimensions and their instances are identified and examined at generalization level as discussed in (Shanks et al. 2004). It is a collection of vocabularies and specifications of conceptualization in a given domain. Hundreds of events of human anatomy, physiology and psychology ecosystems in the form of lexes and terminologies, representing various worldly occurrences and how they can be manifested as dimensions and categorized at different stages of data acquisition. Several anomalies may have been existing while conceptualizing and contextualizing the ecosystem attribute dimensions that describe domain ontologies and their integration (Nimmagadda et al. 2008). The ecosystem events that interpret relationships in similarity, comparison, differential and parallelism characteristics need to be documented while performing data-modelling, -warehousing and -mining. Necessary language rules may be applied in classifying volumes and varieties of worldly data events (Jerko and Nes 2011; Moody and Kortink 2003). Relational, hierarchical and network types of multidimensional data structuring are typical in integrating similarity-comparison-based ontologies. The comparison is performed on relationally- and hierarchically-structured HAPPIER data dimensions as described in Nimmagadda et al. (2016). In another example, the comparison-based ontologies of human ecosystems could be extraction of association between two psychologically affected entities or dimensions (Moody and Kortink 2003). They may have different hierarchies among which, different super-type dimensions are conceptualized with several sub-type dimensions. The events interpreted with similarity, differential and parallel organized attributes are adaptable as domain ontology models and their integration in an integrated framework, feasible in broader contexts of HAPPIER.

**Healthcare Data Dimensions and Characteristics**

In the case of a dimension in the healthcare domain, it is a measure of identifiable existence, or even an emerged conceptualized attribute. The notion of dimension provides semantic information especially among hierarchies of elements of a system. Here element is an individual existence of a composite entity. Entities, objects and dimensions,
used in the ontology modelling process, are reusable in multiple domains. For example, human a composite object (Nimmagadda et al. 2016) that exists within a human ecosystem domain can be reused in multiple applications of physiology and psychology domains. Similar is the case with the human dimension, which quantifies or qualifies within a generic human ecosystem domain is reusable in other domain applications. In the context of digital healthcare ecosystems, entities, objects and dimensions and their attributes play significant roles in connecting multiple domains, where they are often associative (Coronel et al. 2011). In addition, the healthcare data in multiple sources possess heterogeneity and multidimensionality characteristics. These challenges motivated us to carry out multidimensional modelling, considering all domains of HAPPIER, as discussed in the forthcoming sections.

Digital Health and Healthcare Ecosystem

A digital ecosystem is a data-driven concept. The healthcare ecosystem is a complex communion of existing elements and processes occurring in between human anatomy, physiology and psychology with a set of relationships in between their data dimensions. They vary in size and depend on related healthcare data sources, their structures, concepts and contexts. If any chunk of data or information changes, the other parts do change including their semantic, schematic and syntactic contents (Lacasta et al. 2010). When a healthcare ecosystem generates an interpretable new knowledge, we say it is sustainable (Nimmagadda et al. 2016). All the dimensions of the healthcare exhibit tolerance, revealing a balance of semantics between terminologies or vocabularies (Hendry and Friedman 2008). The dimensions are capable of being used, reused, including utility properties of healthcare data. The healthcare ecosystem may be unified metadata with a description of meta-meta-models. Like any other ecosystems, the healthcare ecosystem varies with geographic and periodic contextual dimensions. The knowledge concealed within the healthcare ecosystems depends on their quality, validity, integrity, usability to ultimately test the effectiveness of the HAPPIER in a manner the knowledge of the healthcare process is delivered to the interpreter. In the current context of healthcare research in Big Data scale, an ecosystem is a communion of elements and processes and their chains (conceptualized and contextualized events) in a spatial domain where they constantly interact and communicate through digital media. They can be represented in either Meta or meta-meta-models by Unified Modelling Language and or knowledge-based ontologies with a purpose of describing and visualizing the digital ecosystems in different multidimensional logical schemas.

Data modelling: We use the star, snow-flake and constellation schemas in structuring the data relationships (in terms of ontology descriptions) among different attribute dimensions (Nimmagadda et al. 2016). We describe several such data dimensions and their attributes, connecting the human anatomy, physiological and psychological data events in various schemas and collaborating with their corresponding spatial-temporal attributes. Many interlinked fact instances are documented for building logical and physical data models. The type and size of the data demand a rational modelling approach. Three levels of data modelling are adopted, such as conceptual, logical and physical stages (Gruber 2007). The conceptual model examines the highest level of data relationships, either among entities and or dimensions. In this analysis, more emphasis is on conceptualizing attribute dimensions from heterogeneous healthcare datasets. No attributes and keys are described at construct design stages.

In the logical data modelling stage, the dimensions described with finer details of data relationships are without any concern on physical data organization. Categorically, the data that go through the modelling and integration process are reconciled through the Extract, Transform, Load (ETL) process (Coronel et al. 2011). As a model developer or ontology designer, all the necessary attributes that go through the modelling, mapping and integration process are identifiable with connectable attribute keys. In addition, the framework searches for other connections among common attributes of diverse ecosystems.

For the purpose of exploring and making connections among several volumes of data, ontologies are built. In this context, numerous data relationships are identified and interpreted in the form of multiple dimensions, representative to multidimensional schemas. As given in Nimmagadda et al. (2016), three multidimensional schemas are articulated in HAPPIER contexts, identifying a commonality of key attribute dimensions for connecting the schemas that ascertain the coexistence between domains in HAPPIER. Different schemas characterize how data relationships are built based on ontology descriptions, in which the embedded ecosystems typically manage conflicting data connectivity issues. The dimensional models drawn for human anatomy, physiology and psychology entities with their respective attributes are schematic views of star-schemas (Moody and Kortink 2003). The spatial-temporal dimensions are typical in their representations since they are either geographically or periodically dependent on ecosystem scenarios. Three star-schemas are designed in different domains to build a comprehensive composite schema, compatible and scalable in a multidimensional repository. The ecosystem representing human anatomy, its linked physiology ecosystem and interconnected psychology ecosystems are connected to various alignment characteristics through common attribute dimensions (Nimmagadda et al. 2016).
**Warehouse modelling and metadata description:** This framework can collaborate (for research question 2) HAPPIER multiple contexts and systems. We interpret the type of healthcare knowledge that the theoretical framework can deliver and share among ecosystem providers. The data acquired from gymnasiums in periodic dimensions are documented and used in the current multidimensional modelling. We have added the attribute dimensions that go through the commonality process in the modelling. It is a schema with connectable attribute instances in various fact tables that go into Oracle database programs. The data tables need updates in real-time in HADOOP systems. Figure 1 is a schematic view, conceptualizing and contextualizing the attributes coming from multiple domains of the HAPPIER. The exercise physiology performed in the sport gymnasiums generates a large amount of data related to HAPPIER contexts. The data storage, integration and metadata processing tasks are performed for ecosystem connectivity. An implementation framework with contextual HAPPIER domains and their connectivity are detailed in Figure 1.

![Figure 1. An Integrated framework, implementing the integration process of embedded systems’ data artefacts, showing data views (on the right-hand side)](image)

How the data are integrated to collaborate with different ecosystems has as relevance and scope in research and practice (Shah et al. 2019). Domain ontologies described for data sources in HAPPIER domains are integrated in the data warehouse environment. Integration of embedded ecosystems’ is a novel concept, for managing multiple human, physiology and psychology ecosystems and their heterogeneous and multidimensional data sources. The framework uses domain ontologies with fine-grained-denormalized multidimensional data relationships and their structures (Moody and Kortink 2003). Metadata cubes are further processed for data views, in a way they are interpretable and accessible in new knowledge domains. We have used the public domain data from gymnasiums, where typically the exercise physiology and physiotherapy related workouts taken place and allowed us incorporating and updating the multidimensional data models. We monitor the human body through a static pedalling machine by recording workout time spent, ages and heartrate attribute instances. Five years of data are documented with respect to age, time spent on the machine, heartrates observed attributes as described in H-D-R-C-T-L structure. Psychological observations are interpreted in the form of emotions and tensions during physiological activities occurred at periodic times. The scalar line plots of Figure 1 (on right-hand side) outline as attributed dimensions and their relationships ascertain the association between age, heart-rate and sugar level attributes affected physiological and psychological disorders. How different levels of pedalled-physiological activities affected the human anatomy are explicitly illustrated in Figure 1. As presented in Figure 1, parts of the human body that undergo physio-exercise activity and how it impacts the physio-exercise controlled heartrate, and other psychological events are described. The cardio and fat-burn physio activities are carried out at different levels (of physio exercise), to interpret the effect
of age on heart-rate attributes. As described by arrows in Figure 1, the human anatomy affected various aging, living conditions, the external environment in addition to working conditions, food habits including immunization of body is described. In other words, Figure 1 is a schematic healthcare viewport in which several links are established between human anatomy, various exercise-physiology and interpreted causative psychological events. It has further motivated us to compute data cubes from HAPPIER metadata and their data views. Several data slices extracted using data mining schemes to describe and interpret exercise-physiology events are discussed in the following sections.

**Data mining and visualization artefacts:** The ecosystem researchers and service providers obtain a large amount of digital ecosystem knowledge analogous to analytic information from knowledge-based artefacts (Nimmagadda et al. 2016). Different data mining schemes can explore various data events in different fields, easing the interpretation and analysis of Big Data metadata views (Cleary et al. 2012). Data mining learns anomalies, trends, patterns and correlations among large datasets of healthcare systems. The Periodic dimensions are included in schema designs to explore data events of human ecosystems in different contexts. Data views extracted in periodic instances are used in the interpretation of new knowledge in digital ecosystems. In other words, depicting data views with large population attribute, the physiological and psychological data patterns in multidimensional visualizations can substantiate the explanatory and exploratory data interpretative research. Metadata in the form several data cubes can extract meta-knowledge for visualization and interpretation (Lacasta et al. 2010).

The meta-knowledge may be in the form of decomposition of data attributes in different periodic components (Miller and Han 2001), valuing each data pattern separately and then combining the probable impact of each component in future forecasts (from cuboid data structures). For instance, it is critical to document the changes occurring either in human anatomy data or physiological activity patterns, ascertaining their seasonal, random or trend variations. The research assesses for which human anatomy condition, corrective action is needed as a remedy in the inherited psychological issues. High-performance computing supported by machine learning, classical mining, pattern recognition and visualization brings out new insights of interpretation based on geography and demography. In addition, healthcare professionals assess the results of data mining and visualization with skills to interpret the data and map views to add the value of information including the use and reuse of data models, to be able further to evaluate HAPPIER contexts in spatial-temporal dimensions.

**Results and Discussions**

The section adds other contributions made in the research. Spatial-temporal dimensions are core components of data model representations. The data views relevant to age, heartrate, distance pedaled, Revolutions per Minute (RPM) documented, calories needed including blood glucose levels and human emotions (percentage) are analyzed. The human body affected by the exercise-physiology workout can convey human emotions. The emotions though not measurable, but sentiments can always be related to emotions of the human being. Depending on the immunity and age, the human body can sustain with the period (Miller and Han 2001). Tuberculosis, influenza and pneumonia are various environmentally spread diseases ailing parts of the human body, including its physiological functions, impacting the psychological events (Jerko and Nes 2011). Industries attuned to sensitive environmental conditions also come within the purview of ecosystem construct scenarios of the HAPPIER. The man-made industry activities too severally affect the environment, causative to chronic and communicable diseases, in particular, tuberculosis, asthma and lung cancer diseases that may have interplays. Natural calamities that occur worldwide also affect the embedded ecosystems with added dimensions such as the environment, human population, and diseases in broader HAPPIER contexts. The digital ecosystem, involving the connectivity between human anatomy, physiology, and human psychology has relevance in the design and development aspects of data constructs and logical models through the integrated framework and their implementation in the composited biological realms. The relationship between these ecosystems is hard to simplify and easy to discern through the current research studies. The knowledge may be in the form of decomposition of data attributes in different periodic components valuing each data pattern separately (Nimmagadda et al. 2008). For instance, it is critical to document the changes occurring either in human anatomy data or physiological activity patterns, ascertaining their seasonal, random, or trend variations. Various bubble plot views are presented (in the following sections), providing significant both qualitative and quantitative trends between different attributes of HAPPIER contexts in spatial and temporal dimensions. Exercise physiology controls the human anatomy including emotions through blood pressure, sugar including obesity (beyond the scope of the study) attribute dimensions.

**Implementation – new knowledge interpretation:** For addressing the research question 3, the metadata views, as interpretable in ecosystem knowledge domains, are evaluated for implementation and effectiveness of the integrated framework (Figure 1). The data interpretation is crucial in the HAPPIER contexts, from which we need to test the validity of the data models, including data warehousing and mining schemes with effective visualization and interpretation artefacts. The ETL procedures facilitate us to reconcile the data quality challenges without
Exercise Physiology Data Trends
Sugar Levels
Emotions Trend

We can calibrate the corresponding attributes in the bubble plots of human psychological and physiological data trends, such as insulin levels of the human body that impacted indirectly by the human emotions and other psychological disorders (Figure 2b). In HAPPIER metadata viewpoint, different types of trends are illustrous for interpretation. As shown in Figure 2c, the cardio and fat-burn attributes interact and communicate within multidimensional repositories, ensuring positive and constructive physiological function forecasts, easing the ecosystem interpretation complexities. The constructs and models linked with HAPPIER are necessitated in healthcare research projects. The exercise-physiology undertaken in gymnasiums is real motivation. The connectivity established between human anatomy, physiology and psychology can facilitate perception of human ailments and their mitigations. The findings answer the research purpose.

Figure 2. (a) Data Cube (b) Bubble plot views of multidimensional data attributes among exercise physiology entities (c) Scatter line plot extracted between age and heart rate attributes

Bringing information value in healthcare research (research question 3): Information value is measured with gains attained by reducing uncertainties from framework implementations. Ease of use and reuse of artefacts and their linked framework is provided in the implication of the research. In addition, we use published data sources (GHO and GHE 2017) to test and validate the framework articulations, their artefacts and results. The periodic time and age are key dimensions of data models that represent various demography and geography events. We further take advantage of spatial-temporal data dimensions in the multidimensional modelling. Spatially distributed data events associated with male population attribute instance (percentage) affected by blood pressure, diabetes and obesity prevalence attribute instances are documented and modelled in multidimensional data warehouse schemas.

The metadata constructed in cuboid structures is used to mine, visualize and interpret different data views in spatial-temporal dimensions (Figure 3a). The latitude and longitude attributes of different countries are converted into Cartesian easting and northing coordinates for representing the multidimensional spatial data events. Data cubes are integrated metadata models that can deliver metadata views to various clients or patients. Metadata models comprise of healthcare-related attribute models with summarized results of patients and their ailments with medical remarks. The lobes interpreted as encircled in Figure 3b suggest the connectivity between spatial data events associated with blood pressure, diabetes prevalence and obesity attributes. For interpreting the HAPPIER contexts in temporal dimension as demonstrated in Figure 3c, we plot different attribute instances that represent the male population (%) with normal, low and high raise blood pressure events. Though regressions are computed in the form of orthogonal polynomials and correlation coefficients between attribute instances, but the current scope is show the trends of Blood Pressure (BP) raise ranges with period attribute instances. It is interesting to observe, with increasing periodic intervals, a noticeable decrease in blood pressure levels. Here the size of each bubble indicates the magnitude of the rise in blood pressure attribute instances at their corresponding periodic values.
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Figure 3. (a) Data Cube (b) Bubble plot drawn among Blood Pressure (BP) instances in spatial dimensions (c) Bubble plot view extracted in BP ranges in periodic instances from metadata model

Research Audience and Beneficiaries

As per research question 4, largely the research contexts in the article address the Big Data-size healthcare project and the information value attained. Healthcare professionals, exercise physiologists, physiotherapists and health informatics analysts including medical practitioners and social-welfare institutions are beneficiaries of the research.

The conclusions, Limitations and Future Outlook

The conclusion states the research claim made by the authors. Easing the complexity of systems and extracting new knowledge from systems’ connectivity are contributions of IS-guided digital healthcare ecosystems. The contextual issues and challenges, such as HAPPIER is resolved using BIG Data tools and technologies. We have firmly up the concept of data integration, contemplating its rigor and robustness in the systems integration and interoperability including implementation of the framework in the HAPPIER contexts. Analyzing the heterogeneity and multidimensionality of unstructured data sources within an integrated holistic digital ecosystems’ framework is a much-needed research. The connectivity and coexistence between systems help us understand the issues not only by individual systems but embedded systems of HAPPIER. Models built based on the existing data sources have further scope of extending them in the interrelated systems, keeping in view the evolving digital human ecosystem. Integration of multidisciplinary data in the digital world has an incredible influence on knowledge discovery that can change mere understanding and perception of the embedded ecosystems. Fine-grained multidimensional data structuring has an added advantage for an effective data mining, visualization and interpretation. Human anatomy plays a significant role in embedding of physiological, psychological ecosystems and their data management. Understanding of human anatomy has relevance on its inheritance and coexistence. Though different scopes impact the human anatomy and the connectivity among ecosystems, the HAPPIER continues to be explicitly an indisputable phenomenon and endures to attract future healthcare research audience. Data qualities and their reconciliation in the modelling process are key challenges. The ETL is time a consuming process. To implement the research outcomes successfully, professionals involved in the HAPPIER projects need collaborative efforts between domain experts.

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