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Managing Embedded Digital Ecosystems in Pandemic Big Data Contexts

Completed research paper

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Abstract

The embeddedness of ecosystems interpreted as the connectivity between data sources has been the research focus of ecosystem service providers. Heterogeneity of data sources, linked with embedded systems, is challenging in the ecosystem integration process. Big data is an added motivation in the ecosystem integration process. The purpose of the research is to provide an improved understanding of ecosystem inherent connectivity by integrating multiple ecosystems through their big data in a multidimensional repository system, with a focus on data analytics. We need an architecture to drive the composite congruence existing between disease-human-environment-business systems. We propose an Embedded Digital Ecosystem Architecture (EDEA), from which the associations hidden among big data sources of multiple ecosystems are analysed in new knowledge domains. We construe in our research that pandemic-related disease ecologies have connectivity with the human, environment and economic ecosystems, ascertaining the potential benefits of data science in embedded digital ecosystems' research.

Keywords: Pandemic health, embedded digital ecosystems, Big data, human-pandemic-business

1 Introduction

The ecosystems in which we live in and diseases that exist in environments may have connections (Kemp 2004). The ecosystems are interlinked, and each is influenced by the other. Humans are more likely to be healthier in less disease-prone and pristine environments. We may surrender to different diseases, if the integrity of the environment alters, affecting the balance between diverse ecosystems. Thus the phenomenon of interconnectivity is interpreted, construing embeddedness between ecosystems. Using constructs, models and methods, various researchers have attempted to describe and connect multiple ecosystems digitally. Neuman (1999); Vaishnavi and Kuechler (2004) articulate constructs, models and methods, while developing information system articulations. They have added concepts and tools in the integration process of ecosystem representations (Kemp 2004). A domain model thus verified presumably can validate the related problem solutions. For example, composite domains *disease-human-environment-economics* inherit with numerous entities and dimensions through common attributes, ascertaining their connectivity. The ecosystems embed with several composite domain models, implanting with hundreds of attributes that represent egghead ecologies, in which numerous vocabularies and axioms are construed. Sidhu et al. (2009) describe numerous composite attributes in conceptual modelling requirement analysis. The authors have chosen a composite domain model to describe the relationships between dimensions of *disease-human-environment-economics* architectural congruent associativity*,* with well-defined constraints and set of business rules. In such contexts, we explore the scope of big data, multiple interconnecting domains in metadata structures with meta-knowledge. Several plot and map views are needed from warehoused cuboid metadata to present and interpret new domain-knowledge emerged from embedded ecosystems.

2 Constraints of Existing Information System (IS) Articulations

We analyse the existing IS artefacts that may have constrained the interpretation of congruence between multiple ecosystems. Indulska and Recker (2008); O'Brien and Marakas (2009) describe existing limitations of IS development methodologies in managing application domains associated with heterogeneous and multidimensional embedded ecosystems. The development effort is constrained by type and size of heterogeneous data sources, including the existence of systems, domains, their connectable attribute dimensions. Managing diverse disease-human-environment-economics domains has challenges, especially in spatial-temporal attribute dimensions such as geography and demography, explicitly the country, disease, culture, human-size, including their location (coordinate data) information (Milner-Gulland 2012). Generalization cannot make abstraction for applications in dynamic ecosystem environments in which big data play key roles (Schermann et al. 2014). Governing such IS artefacts may not be compatible and user friendly within tolerant business contexts, unless human ecosystems are analysed, including diseases affected by pandemic illnesses. Heterogeneity and multidimensionality are added challenges in integrating multiple ecosystems, extracting new knowledge and adding values to the embedded ecosystem solutions. We simulate disease-human-environment-economics systems, in which several domains in close hierarchies, with several attribute dimensions, are interpreted for their congruent associativity. If an attribute dimension gets interrupted in an ecosystem, other dimensions closely associated to it, get disrupted, implying that all the dimensions described here, are inherently interconnected. The disease, human, environment and economic ecosystems are known to have inherently interconnected and embedded, in which the data volumes and varieties are not easy to manage, including their integration process. We propose new approaches for managing the embedded ecosystems, conceptually describing their attribute dimensions in a variety of heterogeneous data structures.

3 Significance and Motivation of the Research Work

Ecosystems in the current contexts are spatial-temporal, and their data sources are mostly unstructured and or semi-structured. In addition, they are heterogeneous and multidimensional. Initial motivation is from the existence of diverse ecosystems and their data sources in spatial-temporal dimensions. Another big motivation is from real a build-up of Big Data, sourced all around ecosystems. Description of such Big Data and their modelling have an enormous impact on ecosystem representation, interpretation and analysis. Establishing the communion between multiple ecosystems in the current pandemic contexts is the highlight of the research and demanding in making and delivering quality ecosystem services. We construe not only the connectivity between diverse systems that appear to have inherently interconnected as described in Figure (1) and their unstructured and heterogeneous database systems but explore and discern the cognition of connectivity of the pandemic influence on human-disease-environment-economic ecosystems. For digitally connecting multiple ecosystems, in our research, we conceptualize the need for assimilating congruence between disease-human-environment-economics ecosystems and emphasizing their connectivity with sheer volumes and varieties of big data (Nimmagadda and Rudra 2017). The authors have chosen multiple domains in diverse ecosystems to analyse the inherent interconnectivity, in which each domain emerges with dependence on the other, with agreeable concepts of inheritance and polymorphism (Liberman et al. 2011; Vaishnavi and Kuechler 2004). Domain experts and ecosystem researchers involved in big data-related pandemic healthcare projects need holistic data modelling methodologies with unified IS architectural frameworks. We make use of domain ontologies (Sidhu et al. 2009) in the form of data constructs and models that can characterize interconnectivity and interoperability utility properties. Large-size multidimensional repositories are demanding flexible changes for managing complex embedded ecosystems, which may have surrendered by pandemic illnesses. Embedded ecosystems' data analytics done in different spatial-temporal dimensions can explore new pandemic knowledge from coexistent ecosystems to minimize the risk of pandemic interpretative-illnesses.

4 Related Work

Inadequacies existing in the current models are discussed in this section. Design and development of embedded ecosystems, human-disease-environment-economics are challenging. Their inherent intricacy is difficult to comprehend with simple conceptualization and contextualization descriptions, including generalization and specialization features (Sako 2018). However, we explore each ecosystem's research lacuna within the existing interpretations.

Human Ecosystems: Pickett et al. (1997) underscore the need of integrated concepts, motivating ecologists, social scientists and interconnected human ecosystems in a conceptual framework. Various human activities are added as social attributes in the framework. Spatial heterogeneity and organizational hierarchies can be resolvable by the conceptual framework, involving human ecosystems. The authors illustrate the ecosystem research with urban and metropolitan areas and their networks. Interactions between human ecosystems and other ecological systems tend to interpret various biodiverse misgivings. Envisaging human attitudes towards ecological systems and optimum use of resources can counteract these misgivings. The authors in Milner-Gulland (2012) deduce an inter-disciplinary approach to measure and quantify the interactions between decision-makers' biodiverse dimensions. Laustsen (2006) presents a nursing ecological theory incorporating the concepts of global ecosystems, community interrelationships derived from ecological sciences. The theory may guide the nursing profession in new holistic care and build relationships between infected patients and linked ecological systems. The authors in Mori et al. (2012) provide a conceptual model to describe how the loss of response diversity may have caused degradation through decreased ecosystem resilience.

Infectious Disease Ecosystems: Wang et al. (2020) provide the summary of the Coronavirus that originated in Wuhan, China, suggesting extra care of older people, who may not have an immune system to withstand to the infectious diseases. The authors have investigated 138 Wuhan patients to acquire the Coronavirus data, based on age, previous diseases and gender (as characteristics of the human ecosystem). However, the authors have not interpreted the impact of pandemic infection on general-wellbeing of the human ecosystem. We interpret large-scale pandemic outbreaks of infectious diseases that can increase morbidity and mortality over wide geographic contexts causing significant damage to economic, social and political settings. Hannah et al. (2020) describe the significance of sanitation attribute in pandemic scenarios, and we incorporate these dimensions in dimensional modelling.

Environment Ecosystems: Madhav et al. (2017) provide facts with increased global travel, integration, urbanization, changes in land use, exploitation of the natural environment, affecting environment settings. The authors review the concept and history of the pandemic, how it affected the general wellbeing, human ecosystems, and economic, social settings, including the global security challenges negatively (Qiu et al. 2017). Li et al. (2020) discuss a deeper understanding of the interaction between coronavirus and the innate immune systems and the risk of lung inflammation. The research provides a scope of linking the coronavirus with related diseases and illnesses. Martinez-Harms et al. (2012) use secondary data sources to map and evaluate the ecosystem services in sustainable supply-chain settings. The data sources, types of data sources in the spatial scale are used to build ecosystem service models. Various cultural and biophysical data are used to examine the relationships and develop models using environment variables.

Business or Economic Ecosystems: Boffoli et al. (2010) describe the business ecosystem as an organizational approach, allowing competitive enterprises to cooperate with each other. The authors build a theory based on empirical experimentation. The authors use process models to organize tools, which allow structuring frameworks swiftly for DBE management. Briscoe et al. (2011) describe the digital ecosystem as a novel optimization technique motivated by biological ecosystems by creating Ecosystem-Oriented Architecture (EOA) where the word "ecosystem" is construed more than just a metaphor. The authors in Clarysse et al. (2014) describe knowledge-based ecosystems to understand the competitive advantages of businesses in financial support network environments. Oh Deog-Seong et al. (2016) publish value-added dimensions in economic development through innovation ecosystems. The authors review the concepts in investment and economic development circles. Hyeyoung et al. (2010) discuss the symbiotic relationships that can benefit the linked ecosystem services in order to achieve business sustainability throughout the life cycle of supply chain ecosystem. The authors emphasize the concepts of mutual alliance and cooperation among businesses to collaborate with flagship healthiness strategies. Letaifa et al. (2013) examine the epistemological and theoretical foundations of the business ecosystems and analyse various managerial challenges, including knowledge management, coopetition strategies, platforms and governance. Winn and Pogutz (2013) aim at motivating the research on how the organizations manage the relationship with the natural environment in new knowledge domains of social ecology and strategic management. Sako (2018) describes key characteristics and multiple actors of business ecosystems that can make innovative, collaborate with businesses and regulate ecological strategies. Sustainability, self-governance and capacity to evolve with time are key characteristics analysed. In the current research, the scope and opportunity of human, environment and disease ecosystems are explored, their close connectivity with economic ecosystems.

5 Description of Proposed Research Approach

The purpose of Figure 1 is to identify and describe various attribute dimensions in diverse ecosystems, how interconnectivity established through *crosslines* and evolved conceptualized attribute dimensions, is described. As presented in Figure 1, several attribute dimensions are classified in diverse ecosystems to interpret the inherent interconnectivity. To validate the connectivity between human-disease-environment-economic ecosystems, we map and model multiple data sources of various ecosystems and present the connectivity in new knowledge domains at later stages under analysis section.

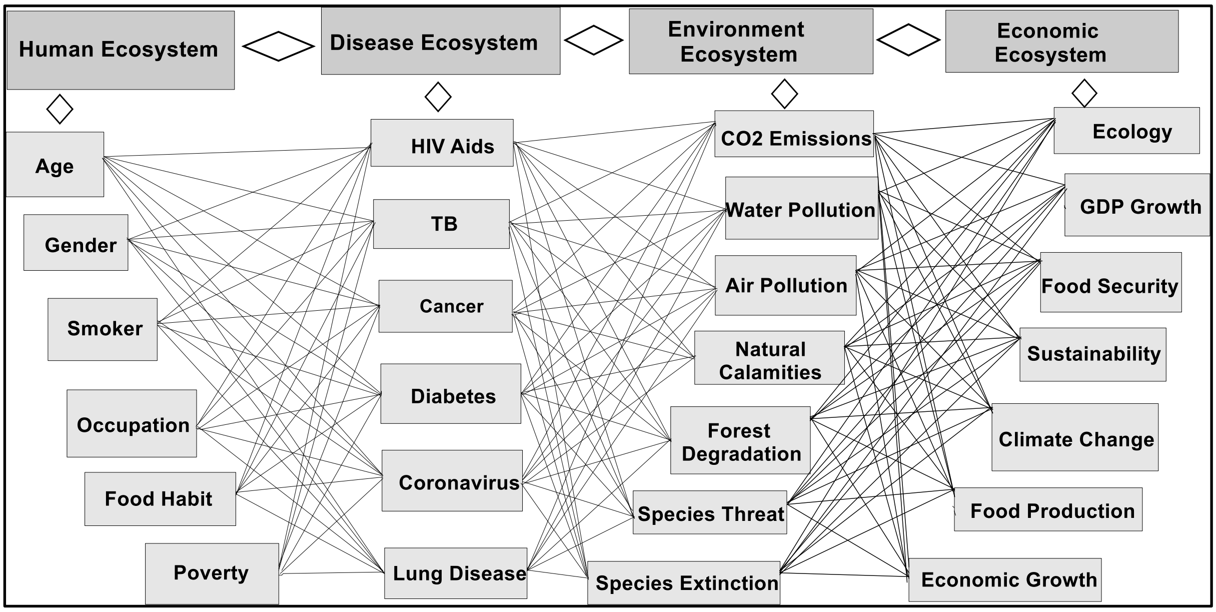

Figure 1: Various dimensions in multiple ecosystems, demonstrating the connectivity (each crossline represents a conceptualized attribute, interpreted between ecosystems)

Embedded systems possess volumes and variety of multiple attribute dimensions and factual instances in big data sources. The proposed IS development methodologies are made generic, acceptable as generalization, specialization, including conceptualization and contextualization features to fix embedded system topographies (Nimmagadda and Rudra 2017). In other words, generalization and specialization, applicable in IS research and practice, are conceptualized and contextualized in multiple data structures. Data structuring in the current research ensures fine-grained data schemas in multiple domains to ensure effective connectivity among ecosystems. For the integration of domain ontologies in different geographic and periodic dimensions, we need innovative IS approaches and address challenges of interpretation of embedded ecosystems. Proposed IS methodology and its practice with heterogeneous big data arena can address human ecosystems broadly with population scale, country-range, sizes and culture attributes, including their ecosystem value chains (Miller and Han 2001; Mori 2012), further extendable to disease, environments and economic scenarios of each country under investigation. The authors propose mixed empirical research with quantitative interpretative methodology with secondary data instances. As described in Figure 1, numerous attributes are interpreted in multiple ecosystem contexts. We emphasize the need for multiple attribute dimensions in the ecosystem mapping and modelling contexts.

5.1 Data Sources Considered in the Investigation and Justification

Variety of dimensions are considered for dimensional modelling in the current research. We interpret multiple attribute dimensions in each ecosystem. Our motivation is the use and reuse of the constructs and models to interconnect multiple ecosystems. The sanitation could be one of the attribute dimensions that can be construed under healthcare ecosystem. We acquire and document secondary data sources to build constructs and models. We justify our research with spatial-temporal attribute dimensions that embed with dissimilar unstructured big data sources of multidimensional human, disease and environment ecosystems. Hundreds of data attributes and their instances are available in the published sources (WHO) for 150 countries' geography and 60 years of periodic data (1960 to 2020) dimensions. However, our focus is on *Pacific-Asia* countries with "geographic and periodic" data dimensions to test and evaluate the phenomena, disease-human-environment-economic ecosystems' inheritance and connectivity.

5.2 Description Ecosystem Components in an Integrated Framework

We emphasize in our research, the need for integrating multiple ecosystems and developing framework articulations to process social-disease-environment-economic ecological activities to improve and map ecosystem services to facilitate decision support systems. We propose domain, data-modelling, schema, warehouse, mining, visualization and interpretation schemes in an integrated framework. The framework can manage all together to store, integrate and process a variety of data sources from multiple domains. The integrated framework narrates domain ontologies, structuring multidimensional data models, mining schemes, visualization and interpretation of metadata procedures. The purpose of Figure 2a is to present the "generalization" and specialization" features. It is a bottom to top representation approach, classifying various ecosystems and their anomalous attributes (Nimmagadda and Rudra 2017). The ontology descriptions further emerge based on spatial-temporal contexts of ecosystems and their linked data sources. Figure 2b is a schematic view of the IS ontology artefact interpreted for analyzing the congruent-associativity between various ecosystems and their logical relationships.

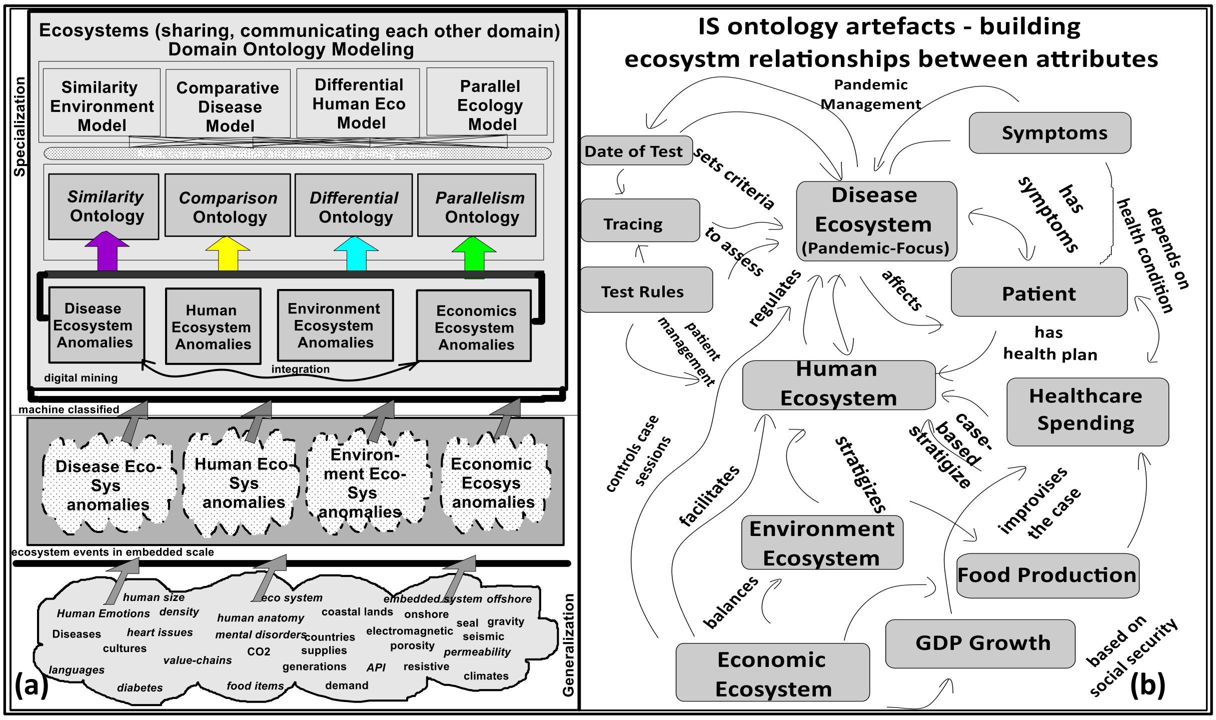

Figure 2: IS articulations connecting (a) multiple domains and systems (b) ontology descriptions

Several ecosystems that interpreted to have digitally interconnected each other are described in the following sections.

Disease ecosystems: The chronic, respiratory, viral, infectious and hereditary illnesses are considered with disease ecosystems (Madhav et al. 2017). The ecosystem explores connections between human and environmental ecosystems. All the data patterns are processed in presentable form for knowledge mapping. In the current contexts, we chose to consider the coronavirus and impact of its infection on the human, environment and economic ecosystems (Martinez-Harms et al. 2012).

Human ecosystems: *Population*, *age* and *gender* along with the living and working conditions, are parts of human ecosystem description. Human anatomy is an integrated structural pattern of the human body system (Sidhu et al. 2009; Nimmagadda and Rudra 2017). Physiological, psychological, emotional data patterns are observed to interpret the overall anatomy of the human system and its connectivity with its closely associated disease and environmental ecosystems (Laustsen 2006). In a pandemic scale, the patterns of infectious coronavirus growth among patients of varied geography and demography of the human ecosystem analysis are considered.

Environmental ecosystems: Air quality is a major concern in pandemic spread areas, because of unbreathable radiation, possibly the *CO_2 emissions* and *air pollutions, mixed with particulate matter* (PM 10 and PM 2.5). The instances observed for each *country*, are geographically interconnected in pandemic contexts that affected the human and disease ecosystems.

***Economic ecosystems**:* Economic growth depends on business activities, but the pandemic environments may have affected business activities, precluding the GDP growth of the country. The disease, human, environment ecosystems, how effectively and inherently the ecosystems embed each other, simulated as IS articulations, are analysed in the following sections.

5.2.1 Domain Modelling

Description of entities associated with knowledge-based architectural setting *disease-human-environment-economic* and building their relationships are highlights of the domain modelling process. As demonstrated in Figure 2a, multiple domains, their dimensions, attributes and their instances are identified. Dimensions identified for modelling are from multidisciplinary sources, from human, disease and environment ecosystems to demonstrate modelling of multiple domains through connections of attribute relationships between ecosystems (Figure 1). Domain ontologies built based on known-knowledge, can explore unknown data relationships and their connectivity through conceptualization and contextualization attributes. These relationships are the mere occurrence of a series of events in multiple ecosystems and their compatibility in an integrated framework.

5.2.2 Big Data - Modelling Congruent Ecosystems

Several dimensions and their attributes are described for modelling human, diseases and environmental data sources. For designing different logical and physical models, factual instances from Big Data volumes and varieties are considered. The authors narrate the type and size of data to consider in the data modelling approach. Three levels of data modelling are adopted, such as conceptual, logical and physical levels (Nimmagadda and Rudra 2017). The conceptual model investigates highest-level data relationships, among either entities, objects or dimensions. In this analysis, more focus is on dimensions, organizing and modelling heterogeneous and unstructured datasets. No attributes and keys are described at the conceptual stage. In logical data modelling, the dimensions are described with more details on data relationships, without any concern on physical data organization. Modelling and mapping data sources from geography and demography may outline and guide us the connectivity process among human ecosystems, affected by disease and environment ecosystems. The ecosystems are interconnected (Kemp 2004); often, they are either interpreted in isolation or misinterpreted when the human ecosystem is managed in its totality.

The spatial-temporal data represent for each country, populations of different ages and genders; including types of viral, chronic, infectious and hereditary data sources of disease ecosystems. *CO2 emissions* and *air pollutions* (particulate matter, PM10 and PM 2.5) are other data sources considered in the environment ecosystems' domain descriptions. The authors propose the star, snowflake and fact-constellation schemas since they are compatible with accommodating in with warehouse environment multidimensional heterogeneous data structuring process. Several such schemas are provided in Figures 3a and 3b. Embedded ecosystems and their associated dimensions are characteristically multidimensional and heterogeneous.

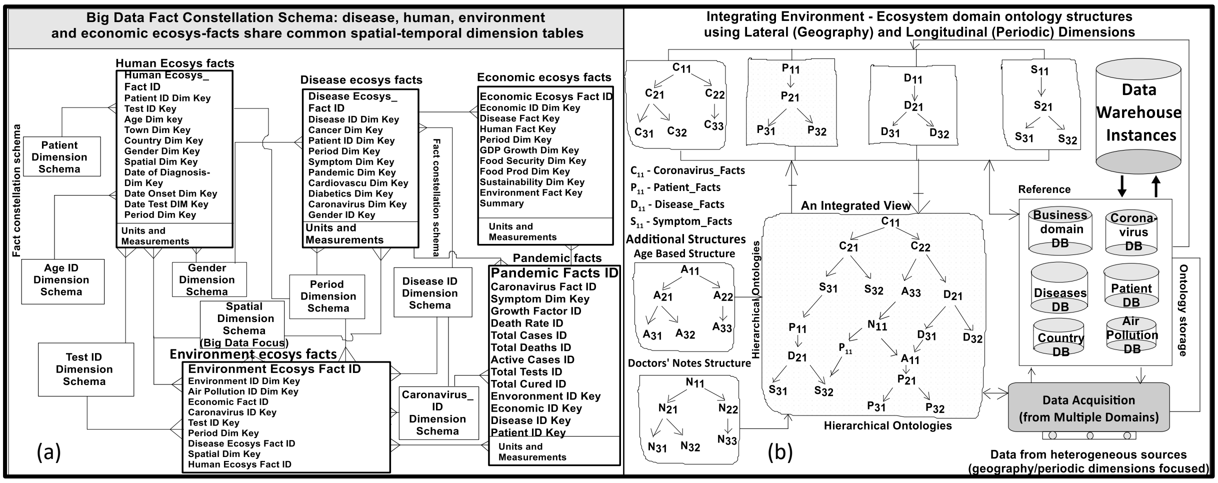

Figure 3: Connecting ecosystems through schema architectures (a) fact constellation (b) ecosystem architecture, connecting various components through hierarchical structure

Spatial-temporal dimensions (Nimmagadda and Rudra 2017), characteristically in nature are geographic and periodic, especially while describing multiple ecosystem situations. Big data being unstructured, heterogeneous and multidimensional, research organizations take advantage of Big data for studies involved with embedded digital ecosystems (Nimmagadda and Rudra 2017). Fact constellation schemas are designed for each ecosystem with conceptualization and or contextualization features. They can make connectivity through one-to-many relationships, as shown in Figure 3a. As an example of a pandemic disease ecosystem, schemas are connectable through common attributes of associated ecosystems. They can even be represented in different hierarchies, with relationships, as allowable in ecosystem contexts. Figure 3b describes several hierarchical relationships interpreted for pandemic based disease ecosystems with several concepts and tools of IS artefacts. Various attributes related to pandemic coronavirus are used in the modelling as described in Figure 3b.

5.2.3 Multidimensional Data Warehouse Modelling – Pandemic Metadata

Multidimensional models designed and developed for various ecosystems are compatible in managing in repositories for storage, integration and processing for metadata, mining and visualization purposes as demonstrated in Figure 3b. Domain ontologies with fine-grained denormailzed multidimensional data articulations are accommodated in the integrated framework. Big data acquired from different sources of the World Health Organization (WHO), associated with multiple ecosystems, are analysed for their connectivity and semantic congruence. Data models represent domain ontologies, purported for identifying and building relationships among ecosystems. Data warehousing is used for integrating data sources from various ecosystems that may have embedded innately. Furthermore, using the multidimensional domain ontologies that integrated with warehouse repository systems, we generate metadata with data cubes. The data views are extractable from cubes for knowledge interpretation and management.

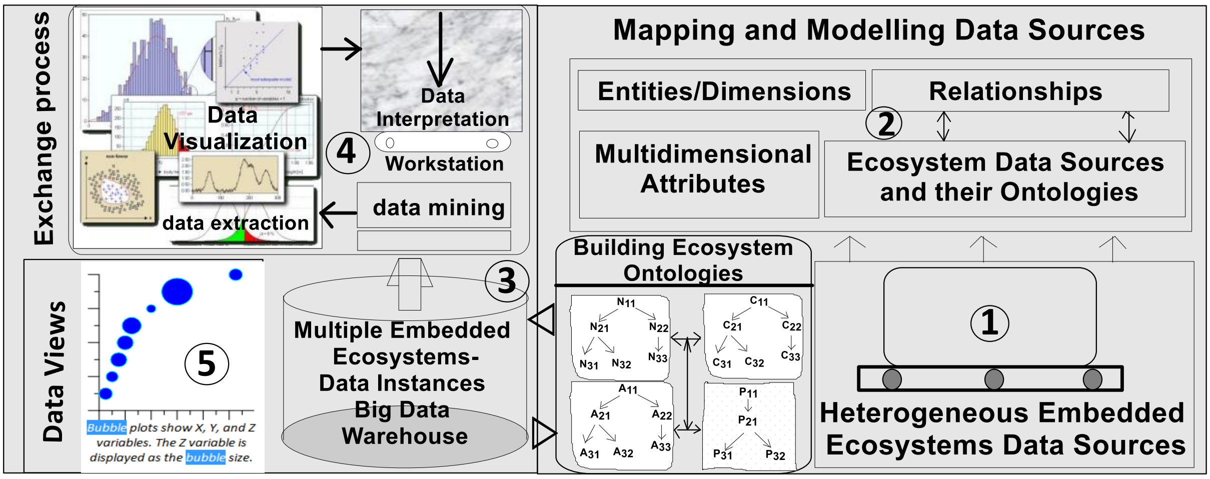

Figure 4: Mapping and modelling architecture

Figure 4 is a workflow for mapping and modelling ecosystems data. The itemized numbers 1, 2, 3, 4, 5 shown as in Figure 4 are assigned to multiple tasks such as data acquisition (1), processing (2, 3), visualization and interpretation (4, 5). Domain ontologies built based on data sources from disease-human-environment-economic ecosystem setting make up their congruence for meta-knowledge. Data warehousing, mining, visualization and interpretation are other tools described in the schematic workflow in Figure 4. Metadata is generated for detailed data mining, visualization and interpretation tasks, as discussed in the following sections.

5.2.4 Data Mining and Visualization Schemes for EDPE Contexts

The authors use several graphic tools (Cleary et al. 2012) that provide one of the most effective means of communication, with 2D and 3D pattern-recognition capabilities, to process and perceive high-quality digital data rapidly and efficiently. Data views extracted from warehoused metadata are presented for visualization and interpretation. By using visualization, data are summarized, and the trends are highlighted. Unknown phenomena are uncovered through various kinds of graphical representation. Metadata in the form several cubes are made for mining and visualization; one of such cubes as narrated in Miller and Han (2001) presents data attributes in periodic dimensions. Several visualization techniques are used to analyse spatial-temporal multidimensional data views of human, disease and environment ecosystems. They represent the population, pandemic disease, environment and economic entities to explore an interpretable new knowledge of embedded systems.

5.2.5 Data interpretation and Meta-knowledge discovery

The extracted data-views are interpreted for evaluable new knowledge, including implementation, the effectiveness of the integrated framework and data models designed in different knowledge domains (Sidhu et al. 2009). Data interpretation is crucial, which can test the validity of data models, data warehousing and mining, even the effectiveness of visualization. In addition, relevance, effectiveness, efficiency, impacts and sustainability criteria are described. The usage of data models in the integrated framework, including implementation of contextual, short- and long-term research outcomes, presented for easting and northing attribute dimensions are other interpretation objectives.

6 Implementation of the EDPE Framework

For offering ecosystem services, the authors evaluate and implement EDPE using several statistical data models, engaging the ecosystem analysts with embedded ecosystems in various spatial-temporal contexts. In addition to envisaging the economic reparation, the computed models are meant for forecasting inputs to healthcare management, based on human and environment conditions. The robust methodology presents definite clues of the ecosystem of ecosystems and their connectivity in Asia-Pacific contexts (as a case study) in the following sections. For example, integration of multiple attribute dimensions from multiple domains can minimize the ambiguity involved in the organizational alignment and or ecosystem connectivity, as shown in Figure 4, the IS development solution can take us to effective implementation and meta-knowledge interpretations.

7 Analysis and Discussions

The authors envisage the relationships among human, disease and environment ecosystems, though they are hard to simplify and interpret. The exponential growth of ecosystem services that demand for new resources has radically changed the phenomenon of relationships and their strengths between interconnected systems. The attributes relevant to environment ecosystem and its linked pandemic related illnesses, natural calamities, air pollutions are connectable to the existing manmade and economic activities, including natural calamities. The holistic modelling approaches to manage embedded ecosystems and their big data are novel research ideas.

7.1 New Insights of Congruent Ecosystems and their Coexistence

IS action research approach, as discussed in Indulska and Recker (2008); Neuman (1999); Vaishnavi and Kuechler (2004), has motivated us to collaborate IS articulations for investigating embedded ecosystems. Though each ecosystem is an information system, which manages big data and information from pandemic health, human, environment and business domains, the process and workflow, how each system functions and operates is inherently the same. The motivation and selection of a particular dimension or composited dimension; the mechanism of each artefact designed, developed and implemented under what changes, their transformations occurred through dimension models, must be explored. IS design may depend on the congruence and associativity between dimensions, their inherent interconnectivity that has definitely influenced IS guided ecosystem implementations. The conceptualization and contextualization of multiple attribute dimensions between embedded systems, have allowed us, introducing the value-chain concepts (Nimmagadda and Rudra 2017). It can add value to the ecosystem design, the connectivity, and inheritance as new insights for congruent IS implementations are made known to ecosystem service providers. The attributes relevant to pandemic diseases, globalization, and technology ecosystems and "value-chains" in logistics environment are driving dimensions and connectable to each other in their functions and operations for transformation and change management. However, type of data and information we use in multiple domains demand a rigor on IS design, development and implementation procedures. As an example, *disease*, *human*, *environment and economic* ecosystems though are different in different domains but have been inherently interconnected, as described in the following sections.

In a 2D bubble plot view, as shown in Figure 5a, we present envelope-visualizations for 14 attributes that are interpreted from various embedded ecosystem scenarios of Australia. The diameter of each bubble can vary in size, providing a way to represent an additional dimension of data. A couple of bubble plot visualizations presented in Figures 5a and 5b suggests near-and far- spatial attribute relationships.

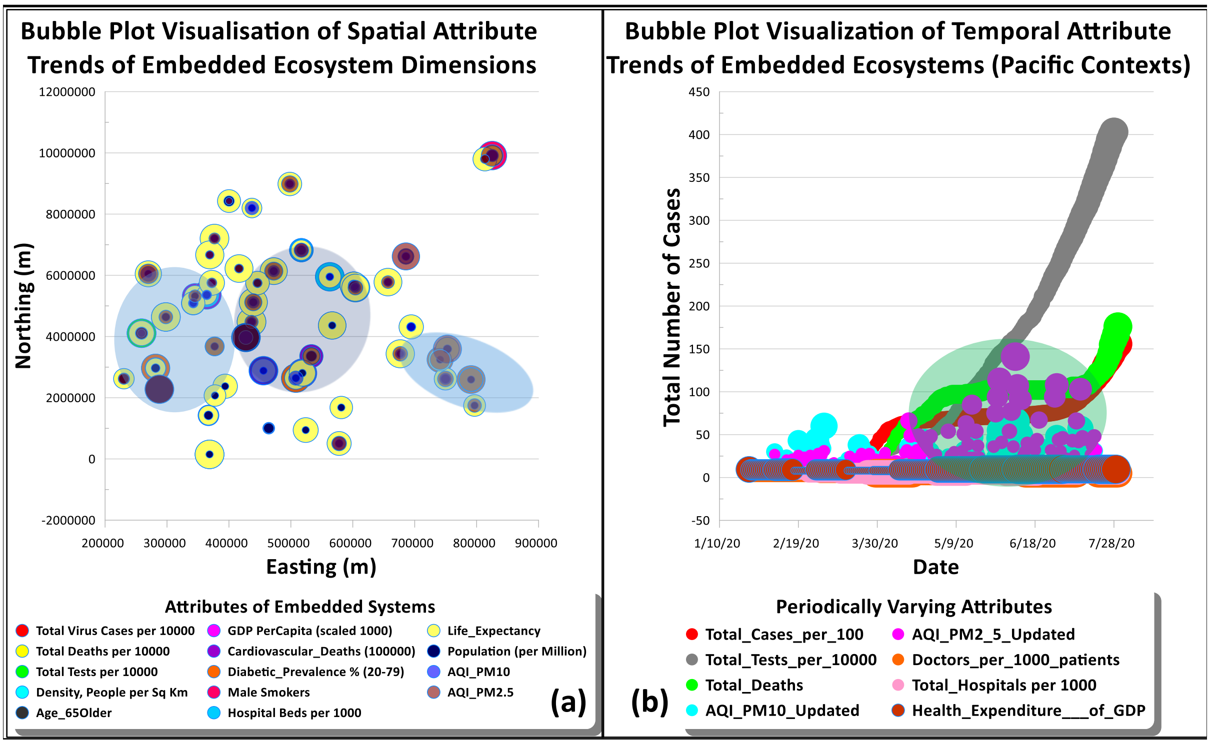

Figure 5: Visualization of Coronavirus Data Views drawn from Ecosystems' Metadata, representing connectivity in (a) Spatial and (b) Temporal Dimensions

Figure 5a represents a variety of multiple attribute dimensions, covering disease-human-environment-economic ecosystems. Connectivity is established between interconnected ecosystems through attributes, as shown in the legend in Figure 5a. The third dimension of data can be represented for the same time span in temporal attribute trends, as shown in Figure 5b. As an example, the bubble plot view is extracted for Australian contexts. Another motivating feature of the bubble-plot view representation is to describe the Tobler's first law of geography, meaning thereby that every bubble is related to other bubbles, ascertaining near bubbles are more interconnected than the distant bubbles. The size of each bubble is ascribed to an attribute strength and magnitude that match with ecosystem durability and sustainability. The bigger the bubble is, the higher the attribute strength, including interpretation of density and orientation attributes and their bubbles. Circular shaped envelopes in Figures 5a and 5b, suggest the coronavirus geographic occurrence that matches with population density attribute. Other associated attributes are superimposed on coronavirus growth attribute to perceive how the attributes fit each other, as a part of embedded ecosystem characteristics.

Having understood the systems, connectivity, local issues and value chains (when the connectivity concept is properly linked to "*value chain*", in support of interoperable quality ecosystem contexts), multinational teams and domain experts mobilize delivery of quality ecosystem services. Categorically, such congruence mechanism can help understand the *disease, human*, *environment* and business ecosystems' connectivity through big data-guided IS articulations. The attributes that vary with spatial-temporal dimensions are total virus cases, total deaths, total tests, population density, age_65, GDP per capita, health expenditure of GDP, cardiovascular, diabetic and smoke-related diseases, hospital beds, life expectancy, AQI (Air Quality Indicators, PM 2.5 and 10). GDP growth has affected, as shown in Figure 5b, though the AQI instances improved. Coronavirus transmission chain may be part of the "value chains", perfectly matches with older-age population and population density attributes. All bubbles are clustered, meaning thereby the attributes are closely connected. The pandemic fatalities match with persons of cardiovascular, diabetic and smoke-related lung diseases.

7.2 Impact of Big Data Systems Dealing with Pandemic Ecosystem

The ecosystems that deal with pandemic ailments are spatial-temporal that interpret Big Data volumes and varieties of data. The integrated strategies can facilitate knowledge discovery from large volumes of data and information hidden among embedded ecosystems. IS research methodology in big data scale is evaluable based on the measure of the impact of pandemic nature of diseases on the human ecosystem and how the entire ecology affects the business organization, in addition to assessing the coexistence between multiple ecosystems. Big data IS research offers embedded ecosystems solutions, alliances with vendors and managing outsourcing projects in geographic scales. IS in big data organizations connects external organizations, such as vendors, business partners, consultants, and research institutions. The big data linked with new IS practices and strategies can change business management, making maintenance easy and flexible as per changes demanded by ecosystems. The impact of IS in disease-human-environment-business congruence is enormous, and it is measured by effective and efficient data mining, visualization and interpretation artefacts of the integrated architecture. In similar research, human, disease, and environment describe ecosystems, though inherently embedded, but may have difficulty in perceiving their connectivity and knowledge as in Kemp (2004), but made simpler in the current research. However, new approaches described in the current research need innovative data artefacts and information solutions to manage multiple embedded digital ecosystems.

8 Conclusions, Future Trends and Scope

Ecosystem researchers have an opportunity and scope of congregating and interacting multiple domains through multidimensional ecosystem articulations. Despite breakthroughs and advances in ecosystems and technologies, identification and description of embeddedness, how disease ecosystems have impacted other ecosystems that remained unresolved, has been resolved in our research. Issues associated with disease ecosystems and the environment resolvable can be perceivable by IS researchers. Ontology-based warehouse modelling combined with data mining, visualization and interpretation, has a future technological edge. Understanding human ecosystems that affected by diseases and environmental issues has implications on saving precious human life. Analysis of air pollution (AQI) in the form of increasing carbon levels or radiation of coronavirus in the atmosphere is much-needed research that can change the perception of connectivity interpreted between human and disease ecosystems. The methodological approach is robust and flexible for managing heterogeneous and multidimensional data sources of embedded ecosystems. Models built based on data sources in Australian contexts have a further scope of extending them in interrelated systems, keeping in view the dynamics of chosen ecosystems. Fine-grained multidimensional data structuring approach proposed can assist effective data mining, visualization and value of interpretation. Human ecosystems play a significant role in embedment of disease, environment and economic ecosystems. Understanding of human ecosystem has significance, by considering its inherent effect on other ecosystems.

References

Briscoe, G., Sadedin, S. & De Wilde, P. Digital Ecosystems: Ecosystem-Oriented Architectures. *Nat Comput* 10, 1143 (2011). https://doi.org/10.1007/s11047-011-9254-0.

Boffoli, N., Cimitile M., Maggi F.M., Visaggio G. (2010) An Approach to Digital Business Ecosystems based on Process Models. In: D'Atri A., De Marco M., Braccini A., Cabiddu F. (eds) Management of the Interconnected World. Physica-Verlag HD.

Cleary, L, Freed, B, and Elke, P. 2012. Big Data Analytics Guide: 2012, Published by SAP, CA 94607, USA, 2012.

Clarysse, Bart, Wright, Mike, Bruneel, Johan, Mahajan, Aarti. 2014. Creating value in ecosystems: Crossing the chasm between knowledge and business ecosystems, Research Policy, 43 (7), pp. 1164-1176. https://doi.org/10.1016/j.respol.2014.04.014.

Hannah, D.M., Lynch, I., Mao, F. *et al.* 2020.Water and sanitation for all in a pandemic. *Nat Sustain* (2020). https://doi.org/10.1038/s41893-020-0593-7.

Hyeyoung, K., Jae-Nam Lee, and Jaemin Han. 2010. The role of IT in business ecosystems, Commun. ACM, 53 (5), pp. 151-156. https://doi.org/10.1145/1735223.1735260.

Indulska, M. and Recker, J. C. 2008. Design Science in IS Research: A Literature Analysis. In Gregor, Shirely and Ho, Susanna, Eds. *Proceedings 4th Biennial ANU Workshop on Information Systems Foundations*, 2008, Canberra, Australia.

Kemp, D. D. 2004. Exploring Environmental Issues – an Integrated Approach, Routledge, Taylor & Francis Group, London, 2004, p. 1-406.

Laustsen, G. 2006. APRN, BC Environment, Ecosystems, and Ecological Behavior, Advances in Nursing Science: January-March 2006 - Volume 29 - Issue 1 - p 43-54.

Liberman, N., Beeri, C. and Kolikant, Y. B. 2011. Difficulties in Learning Inheritance and Polymorphism ACM Transactions on Computing Education, Vol. 11, No. 1, Article 4, Publication date: February 2011.

Li, G, Fan Y, Lai Y, et al. 2020. Coronavirus infections and immune responses, J Med Virol. 2020; 92 424-432. https://doi.org/10.1002/jmv.25685.

Letaifa, S. B., Gratacap, A. Isckia, T. 2013. Understanding Business Ecosystems: How Firms Succeed in the World of Convergence? De Boeck Superieur, 25 Sep 2013 - Business & Economics - 256 pages.

O'Brien, J. A., and Marakas, G. M. 2009. Management information systems, (9th ed.), 2009, Boston, MA: McGraw-Hill/Irwin, USA.

Madhav, N, Oppenheim B, Gallivan M, et al. 2017. Pandemics: Risks, Impacts, and Mitigation. In: Jamison DT, Gelband H, Horton S, et al., editors. Disease Control Priorities: Improving Health and Reducing Poverty. 3rd edition. Washington (DC): The International Bank for Reconstruction and Development/the World Bank; 2017 Nov 27. Chapter 17. Available from: https://www.ncbi.nlm.nih.gov/books/NBK525302/ doi: 10.1596/978-1-4648-0527-1_ch17.

Martinez-Harms, María José, Balvanera, Patricia, 2012. Methods for mapping ecosystem service supply: a review, International Journal of Biodiversity Science, Ecosystem Services & Management, Taylor & Francis, 8 (1-2) PP. 17-25. 10.1080/21513732.2012.663792, https://doi.org/10.1080/21513732.2012.663792.

Milner-Gulland, E. J. 2012. Interactions between human behavior and ecological systems. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, *367*(1586), 270–278. https://doi.org/10.1098/rstb.2011.0175.

Miller, H.J and Han, J. 2001. Fundamentals of spatial data warehousing for geographic knowledge discovery, Geographic data mining and knowledge discovery, 2001, pp. 51-72.

Mori, A. S., Takuya Furukawa, Takehiro Sasaki, 2012. Response diversity determines the resilience of ecosystems to environmental change, Biological Reviews, Cambridge Philosophical Society. https://doi.org/10.1111/brv.12004

Nimmagadda S. L. and Rudra A. 2017. Managing the Embedded Digital Ecosystems (EDE) Using Big Data Paradigm. In: Kei Daniel B. (eds) Big Data and Learning Analytics in Higher Education. Springer, Cham. https://doi.org/10.1007/978-3-319-06520-5_5Neuman, W.L. 1999. *Social research methods, qualitative and quantitative approaches*, 4th Edition, 1999, Allyn and Bacon Publishers.

Oh, D., Phillips, F., Park, S. and Lee, E. 2016. Innovation ecosystems: A critical examination, Technovation, Volume 54, 2016, Pages 1-6, https://doi.org/10.1016/j.technovation.2016.02.004.

Pickett, S.T.A., Burch, W.R., Dalton, S.E. *et al.* 1997. A conceptual framework for the study of human ecosystems in urban areas. *Urban Ecosystems* **1,** 185–199 (1997). https://doi.org/10.1023/A:1018531712889.

Qiu, W., Rutherford, Shannon, Mao, A. and Chu, C. 2017. The Pandemic and its Impacts, Health, Culture and Society, Vol 9, pp. 1-11. 10.5195/HCS.2017.221.

Sako, M. 2018. Technology strategy and management: Business Ecosystems: how do they matter for innovation, Communications of ACM, 61 (4), pp. 20-22. 10.1145/3185780.

Schermann, M, Hemsen H, Buchmüller C, Bitter T, Krcmar H, Markl V, Hoeren T. 2014. Big Data, An Interdisciplinary Opportunity for Information Systems Research, DOI 10.1007/s12599-014-0345-1, Springer Fachmedien Wiesbaden, 2014.

Sidhu, A.S., Dhillon, T.S. and Chang, E. 2009. Data Integration through Protein Ontology, a book chapter published under a title: Knowledge Discovery Practices and Emerging Applications of Data Mining: Trends and New Domains, http://www.igi-global.com/ USA, 2009.

Vaishnavi, V. and Kuechler, W. 2004. Design Research in Information Systems, July 27, 2004, URL: http://www.isworld.org/Researchdesign/drisISworld.htm.

Wang, W. M.B. Tang, J. and Wei, F. 2020. Updated understanding of the outbreak of 2019 novel coronavirus (2019-nCoV) in Wuhan, China, J Med Virol. 2020; 92: 441–447, Wiley.

Winn, M. I., and Pogutz, S. 2013. Business, Ecosystems, and Biodiversity: New Horizons for Management Research. *Organization & Environment*, *26*(2), 203–229. https://doi.org/10.1177/1086026613490173