ENVISIONING uHEALTH
An Ontological Framework

Arkalgud Ramaprasad and Shazia A. Sathar
University of Illinois at Chicago, Chicago, IL 60607, U.S.A.

Keywords: uHealth, Ontology, eHealth.

Abstract: Ubiquitous health care (uHealth) is becoming feasible today, more so than ever before, due to rapid advances in information technology. We can glimpse its possibilities in the care of the wounded in war and the diagnosis and treatment of diseases from a distance. However, the visions of uHealth are many and partial, ill-defined and unclear. We present a set of four ontologies to envision uHealth systemically. The ontologies deconstruct uHealth into spatial, temporal, and semiotic ubiquity. Each aspect of ubiquity is further deconstructed into three components. These ontologies can be used to construct a comprehensive natural-language narrative of uHealth. They can also be used to (a) map the states-of-the-potential, art, and -practice of uHealth, and (b) systematically design the trajectory for the transformation to uHealth.

1 INTRODUCTION

Health care at its core is an interaction based on extensive information transportation and translation – from the patient to the provider, from the provider to the patient, from within the patient to the diagnostician (for example, endoscopy), from the researcher to the clinician, from the provider to the insurer, from the provider to the pharmacist, and so on (Ramaprasad, Papagari, & Keeler, 2009; Ramaprasad, Valenta, & Brooks, 2009). In combination with the internet – a revolutionary information transportation system, evolving into a translation system with the semantic web – there have emerged many new alternatives to traditional face-to-face health care. The new visions of health care seek to transform the processes and outcomes of traditional health care.

Pervasive health care, for example, is defined as "healthcare to anyone, anytime, and anywhere by removing locational, time and other restraints while increasing both the coverage and the quality. The pervasive healthcare applications include pervasive health monitoring, intelligent emergency management system, pervasive health- care data access, and ubiquitous mobile telemedicine." (Varshney, 2007, p. 113) In a similar vein u-Health is defined as "ubiquitous health care, health management and medical services anytime anywhere." (Kugsang, Eun-young, & Dong Kyun, 2009, p. 829) Earlier in the development of these concepts eHealth was defined as "the use of emerging information and communication technology, especially the Internet, to improve or enable health and health care." (Eng, 2001) Another variation of the concept is m-Health, the use of "mobile computing, medical sensor, and communications technologies for health-care." (Istepanian, Jovanov, & Zhang, 2004, p. 405).

Related to the above broad visions of health care are a number of capabilities envisaged because of advances in information technology. The following are some examples. The Bank of Health wherein "[t]hrough a health "ATM" system what would work like banking ATMs, the consumer will have secure, private, and global access to a healthcare "checking account" containing information like blood types, medications, and personal family medical histories." (Ball & Lillis, 2001, p. 6) Bardram envisages "a context-awareness infrastructure in place in a hospital that various clinical applications can access and use to adapt to the context in which they are currently running…a context-aware Electronic Patient Record (EPR), a context-aware pill container, and a context-aware hospital bed." (Bardram, 2004, p. 1574) Intelligent Biomedical Clothing (IBC) could weave together "textile fibers, biomedical sensors and wireless and

Ramaprasad A. and Sathar S..
ENVISIONING uHEALTH - An Ontological Framework.
DOI: 10.5220/0003290004110416
In *Proceedings of the International Conference on Health Informatics* (HEALTHINF-2011), pages 411-416
ISBN: 978-989-8425-34-8

mobile telecommunications" (Lymberis & Olsson, 2003, p. 379) Intelligent agents could actively sense and gather "information across the [health care] delivery network…." (Weagraff, 2005, p. 3) Further they "could provide care themselves….act on behalf of the enterprise to correct faults or provide information in a proactive manner…." (Weagraff, 2005, p. 3).

Each of the many visions of future health care represents a part of the potential. In the parable of the six blind men and the elephant, each man experiences a part of the elephant and infers an incorrect image of the whole. The real elephant remains invisible to all of them (Ramaprasad, 2009) until a wise man integrates the image of the whole from the parts. Similarly, today the 'elephant' called uHealth remains invisible. The objective of this paper is to make it visible. We present an ontological method to envision the complexity of uHealth concisely and comprehensively, using natural English, and at different levels of granularity. It is a method to envision the whole, the parts, and the relationship between the two.

2 ONTOLOGY OF uHEALTH

2.1 Ontology of eHealth

The proposed ontology of uHealth is based on the ontology of eHealth (Ramaprasad, Papagari et al., 2009) shown in Figure 1. It encapsulates the definition of eHealth as 'transporting information to transform health care.' The five axes of the ontology are information, spatial transportation, temporal transportation, semiotic transportation, and heath care. Each axis is defined by a taxonomy (one- or two-level) of attributes. The axes are presented left to right in Figure 1 with connecting words/phrases between the columns.

A natural language descriptor of eHealth can be concatenated by combining a category from each column with the connecting words/phrases (Ramaprasad, Papagari et al., 2009). For example:

- Transporting personal health information intra-enterprise locally in real time as data to transform outcomes of wellness.
- Transporting medical research information inter-enterprise nationally in advance as action to transform outcomes of illness.
- Transporting business financial intra-enterprise regionally in real time as data to transform management of revenue.

Ubiquity in health care is a combination of spatial, temporal, and semiotic ubiquity. We will extend the eHealth ontology to uHealth by including the corresponding axes and desconstructing them further into three components.

2.2 Ontology of uHealth

A colloquial expression for ubiquity is 'any-place, any-time'; it connotes spatial and temporal ubiquity. To these two commonly used axes of ubiquity we add the third axes of semiotic ubiquity – 'any-information'. It connotes the complete semiotic cycle (Ramaprasad & Rai, 1996) – the morphologics, syntactic, semantics, and pragmatics of the generation and application of information. Thus, we define uHealth as 'transporting information ubiquitously – spatially, temporally, and semiotically – to transform health care.' The corresponding ontology is shown in Figure 2. The Information and Health Care axes are the same as in the eHealth ontology; the third (middle) axis is Ubiquity is new and includes the three categories of ubiquity.

The following are six of the 36 basic connotations of uHealth which can be derived from the ontology, each with an example.

1. Transporting personal information spatially ubiquitously to transform health care outcomes. For example, having a person's emergency contact information available anywhere.
2. Transporting medical information temporally ubiquitously to transform health care outcomes. For example, having a person's prescription information available anytime.
3. Transporting business information temporally ubiquitously to transform health care quality. For example, knowing a clinic's complete billing history to determine potential fraud.
4. Transporting personal information semiotically ubiquitously to transform health care quality. For example, interpreting socio economic data to tailor treatment plan.
5. Transporting medical information semiotically ubiquitously to transform health care quality. For example, interpreting genetic information to tailor drug treatment individually (Eichelbaum, Ingelman-Sundberg, & Evans, 2006).

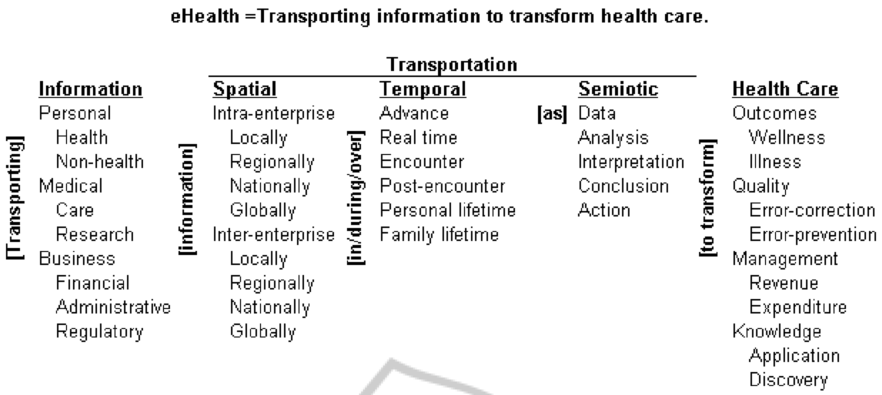

Figure 1: Ontology of eHealth.

6. Transporting personal information semiotically ubiquitously to transform health care knowledge. For example, recommending actions based on knowledge of personal and family demographic history.

We can refine the concepts of spatial, temporal, and semiotic ubiquity further as discussed below.

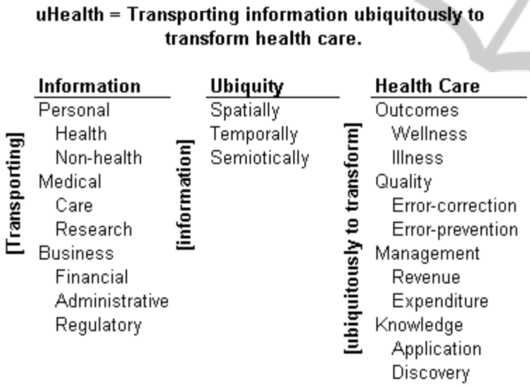

Figure 2: uHealth Ontology.

2.3 Ontology of Spatial Ubiquity

The concept of spatial ubiquity can be deconstructed into three components, namely: spatial distribution, spatial range, and spatial locus. These three are shown as separate axes in Figure 3. The figure articulates the statement 'transporting information spatially ubiquitously to transform health care'. The Information and Health care axes of the ontology are the same as in Figures 1 and 2.

Spatial Distribution describes the density of the ubiquity. At the lower extreme ubiquity may be defined by the ability to transport information from/to fixed locations. As long as the relevant fixed locations are covered one could describe the system as being minimally ubiquitous. For example, as long as all the clinics of a health care provider are covered, a system may be described as being ubiquitous. At the upper extreme ubiquity may be defined as the ability to transport information from/to a continuous space. Thus, the requirement for ubiquity may be anywhere in the geographical region covered by the clinics. Between these two extremes spatial distribution may be defined by networked points or mobile points from/to where information has to be transported.

Spatial Range describes the scale of the ubiquity. The ubiquity may be at a very close range; for example, within a hospital room. Or, it may be at a remote range; for example, anywhere within a city, region, or country.

Spatial Locus describes the focus or origin of ubiquity. It may be any one or a combination of the health care providers listed in Figure 3. It may also be described differently in terms of the facilities such as clinics, hospitals, etc.

Combining Spatial Distribution and Spatial Range, spatial ubiquity may range from fixed points at a very close range to continuous points at remote range. Further combining it with Spatial Locus, the technology required for transporting information from/to fixed points at very close range from/to patient would be different from that for transporting information from/to continuous points at remote range from/to patients. Thus, spatial distribution, range, and locus can impose different requirements on a uHealth system.

2.4 Ontology of Temporal Ubiquity

The concept of temporal ubiquity can be deconstructed into three components, namely: temporal interval, temporal range, and temporal locus. These three are shown as separate axes in

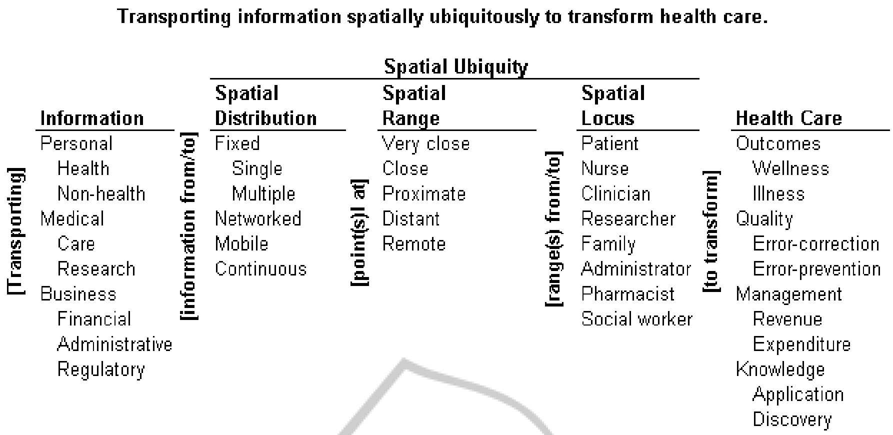

Figure 3: Ontology of spatial ubiquity.

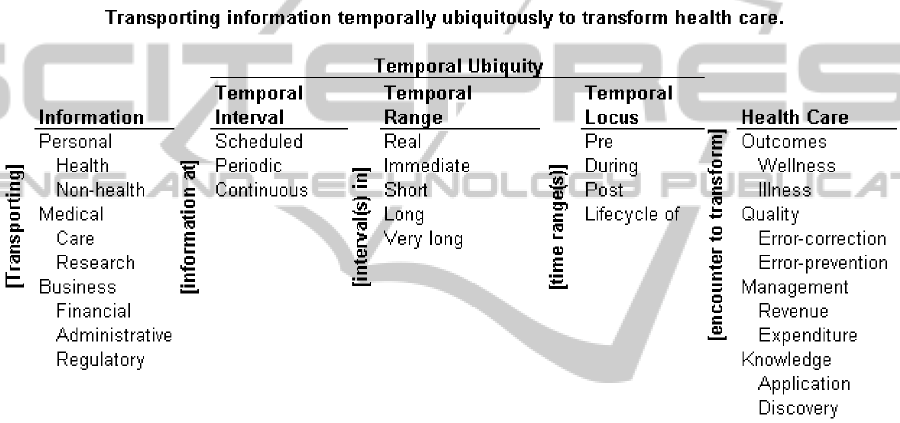

Figure 4: Ontology of temporal ubiquity.

Figure 4. The figure articulates the statement 'transporting information temporally ubiquitously to transform health care'. The Information and Health care axes of the ontology are the same as in Figures 1 and 2.

Temporal Interval describes the frequency of transportation of information. It ranges from the Scheduled through Periodic to Continuous. Scheduled transportation would be the least ubiquitous temporally, Continuous the most. The temporal interval for transportation would be determined by the temporal characteristics of the information. Scheduled ubiquity may be adequate for a low frequency or unchanging information such as weight and height; Continuous ubiquity may be necessary for high frequency information such as a heart monitor from an ambulance.

Temporal Range describes the period over which information has to be transported for uHealth. Real time anchors the low end of the axis; Very long periods, which may be as long as a person's life time or even a family's lifetime (in the case of certain genetically inherited diseases), anchors the high end of the axis. Between the two anchors are three categories labeled Immediate, Short, and Long. The clock-time equivalents of these ranges may vary between contexts. Real time range for lifestyle change may be Very long range for chronic heart failure.

Temporal Locus describes the location of the temporal range relative to an encounter. It ranges from Pre (before) the encounter to During, Post, and the Lifecycle of the encounter. For transient events such as a common infection the locus may be just during the encounter; on the other hand, for a chronic condition such as diabetes it would have to be during the Lifecycle of the disease.

Combining Temporal Interval and Temporal Range, temporal ubiquity may range from Scheduled intervals in Real time range to Continuous interval in Very long time range. Further combining it with Temporal Locus, the technology required for transporting information at scheduled intervals in real time range Pre encounter would be

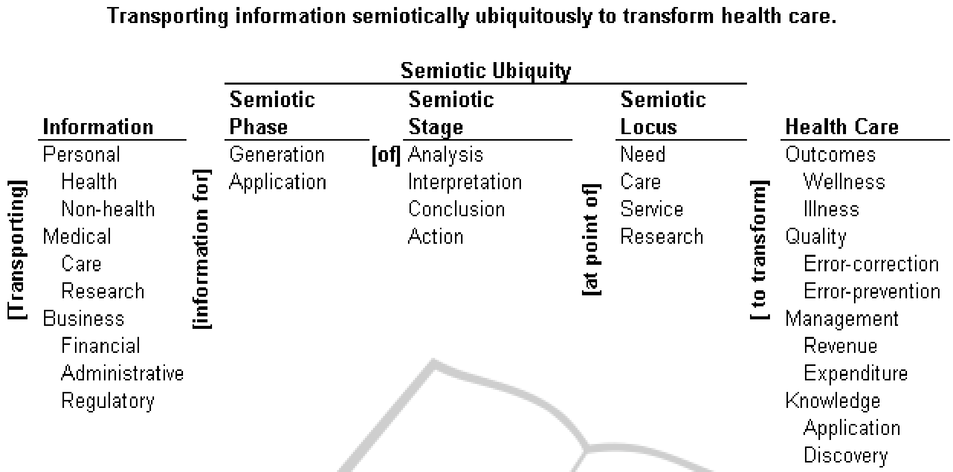

Figure 5: Ontology of Semiotic Ubiquity.

different from that for transporting information at Continuous interval in Very long time range for the Lifecycle of the encounter. Thus temporal interval, range, and locus can impose different requirements on a uHealth system.

2.5 Ontology of Semiotic Ubiquity

The concept of semiotic ubiquity can be deconstructed into three components, namely: Semiotic Phase, Semiotic Stage, and Semiotic Locus. These three are shown as separate axes in Figure 5. The figure articulates the statement 'transporting information semiotically ubiquitously to transform health care'. The Information and Health Care axes are the same as in Figures 1 and 2.

Semiotic Phase describes the two broad phases of the semiotic cycle, Generation and Application of information(Ramaprasad & Rai, 1996). Repeated completion of both phases is necessary for translating information into action and obtaining information about action (Ramaprasad, Valenta et al., 2009). Clinical research, for example, may focus more on the Generation of information; clinical practice, on the Application of information. Similarly, continuous monitoring devices may focus primarily on the ubiquitous Generation of information with a small component of Application to discover potential emergency alerts. An aspect of semiotic ubiquity is the inclusion of both phases.

Semiotic Stage describes the four broad stages of the semiotic cycle: Analysis, Interpretation, Conclusion, and Action. The first three correspond to the commonly used syntactics, semantics, and pragmatics (Ramaprasad & Rai, 1996) categories. The value of information is enhanced at each stage. The full value of information is realized only when the cycle is complete. An aspect of semiotic ubiquity is the completion of all the four stages.

Semiotic Locus describes the location of the semiotic process. It may be at the point of Need, Care, Service, or Research. Other locations may be added to the list. The Semiotic Locus may also include multiple locations. Ideally, uHealth would entail the ability to complete the semiotic cycle from any locus – the ability to translate information at any place and time.

Combining Semiotic Phase and Semiotic Stage, Semiotic Ubiquity would include Generation and Application of Analysis, Interpretation, Conclusion, and Action. The integration of these at any Locus would be the objective of Semiotic Ubiquity. The practice of evidence based medicine, for example, requires the ability to transport Medical information for Generation/Application of Interpretation, Conclusion, and Action at the point of Care.

3 CONCLUSIONS

Ubiquity is polymorphic. Thus the meaning of uHealth can vary by the context and the corresponding needs. The ability to access one's electronic medical records (EMR) in any physician's office in a geographical region may be the state-of-the-need of ubiquity in a developed country. On the other hand, the ability to access a physician within half a day's travel by foot may be the state-of-the-need in a developing country. A physician practicing evidence based medicine (EBM) may desire semiotic ubiquity at the point of care through access to online reviews, journals, and decision support tools. A physician practicing in a remote village may be content to collect the data from the patient and send it by snail-mail for analysis, interpretation, and action to a specialized tertiary care hospital.

Effective strategies are systemic and systematic responses to a problem. For uHealth, they have to be based on the integrated image of the whole 'elephant' called uHealth, not on fragmented images of its parts. If uHealth strategies are to be effective in the new internet age, they have to be designed, developed, and implemented systematically in the context of the particular health care system. Ad hoc, fragmented strategies will be ineffective.

The ontological framework for conceptualizing uHealth discussed in this paper provides a language and logic for designing and developing a coherent uHealth strategy. The framework can be used to map the states-of-the-art, -need, and –practice; and from these maps to assess the gaps between the states and determine strategies to bridge the gaps. The ontologies can be adapted to a context by changing the axes and taxonomies accordingly. Thus, one can envision the trajectory of transformation from traditional health to uHealth in the age of the new internet – perhaps the age of the Übernet.

REFERENCES

Ball, M. J., & Lillis, J. (2001). E-health: transforming the physician/patient relationship. *International Journal of Medical Informatics, 61*(1), 1-10.

Bardram, J. (2004). *Applications of context-aware computing in hospital work: examples and design principles.* Paper presented at the SAC '04, Nicosia, Cyprus.

Eichelbaum, M., Ingelman-Sundberg, M., & Evans, W. (2006). Pharmacogenomics and individualized drug therapy. *Annual Review of Medicine, 57*, 119-137.

Eng, T. R. (2001). *The eHealth Landscape: A Terrain Map of Emerging Information and Communication Technologies in Health and Health Care*: Princeton, NJ: The Robert Wood Johnson Foundation.

Istepanian, R. S. H., Jovanov, E., & Zhang, Y. T. (2004). Guest Editorial Introduction to the Special Section on M-Health: Beyond Seamless Mobility and Global Wireless Health-Care Connectivity. *Information Technology in Biomedicine, IEEE Transactions on, 8*(4), 405-414.

Kugsang, J., Eun-young, J., & Dong Kyun, P. (2009). *Trend of wireless u-Health.* Paper presented at the ISCIT 2009, Incheon, Korea.

Lymberis, A., & Olsson, S. (2003). Intelligent biomedical clothing for personal health and disease management: state of the art and future vision. *Telemedicine Journal and e-Health, 9*(4), 379-386.

Ramaprasad, A. (2009). Ubiquitous Learning: An Ontology. *Ubiquitous Learning: An International Journal, 1*(1), 57-65.

Ramaprasad, A., Papagari, S. S., & Keeler, J. (2009). eHealth: Transporting Information to Transform Health Care. In L. Azevedo & A. R. Londral (Eds.), *Proceedings of HEALTHINF 2009 – Second International Conference on Health Informatics* (pp. 344-350). Porto, Portugal: INSTICC Press.

Ramaprasad, A., & Rai, A. (1996). Envisioning management of information. *Omega-International Journal of Management Science, 24*(2), 179-193.

Ramaprasad, A., Valenta, A., & Brooks, I. (2009). Clinical and Translational Science Informatics: Translating Information to Transform Health Care. In L. Azevedo & A. R. Londral (Eds.), *Proceedings of HEALTHINF 2009 – Second International Conference on Health Informatics*. Porto, Portugal: INSTICC Press.

Varshney, U. (2007). Pervasive healthcare and wireless health monitoring. *Mobile Networks and Applications, 12*(2), 113-127.

Weagraff, S. (2005). *The Case for Intelligent Agents Preparing for the future of care.* Paper presented at the, International Conference on Computational Intelligence for Modelling, Control and Automation, 2005 and International Conference on Intelligent Agents, Web Technologies and Internet Commerce.