CaDHealth: Designing and Prototyping for Cross-Boundary Decision Support in E-Health

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Abstract

This paper presents the design of CaDHealth, a system aimed at enabling knowledge and work practice transfer among clinicians across geographical, regional and workplace boundaries for effective clinical decision support in e-health. The system offers a unifying structure that allows clinicians to make sense of clinical work situations across regional and workplace boundaries in an e-health environment. The approach we have taken in CaDHealth is motivated by the fact that 1) patterns of clinical work practice have been found to vary significantly across work settings, and 2) the contextual cues and practice-based knowledge, which are offered by common problem solving contexts in co-located work settings, and which enable clinicians, in such settings, to share information and knowledge to support one another's clinical decision making do not exist in e-health and other distributed work contexts. In particular, we highlight a number of user-informed design considerations, and describe the architecture and prototype of CaDHealth.

1. Introduction

Over the last twenty-five years, advances in information and communication technology have led to an increasingly "flat world" (Friedman, 2005) where such newly emerged technologies as e-collaboration, social networks, distributed agents and mobile computing make it possible for individuals to interact with one another easily and agilely regardless of time and space. Recently, knowledge workers, technical personnel and experts from various domains including healthcare have become increasingly attracted to this new form of collaboration as a way of harnessing globally distributed knowledge and leveraging collective intelligence and social creativity across organisational, regional and workgroup boundaries for improved decision making (see, for example, [1], [2], [3], [5], [6], [7], [11]).

However, clinicians and healthcare professionals in different hospitals tend to have different practices, which have proven to be valuable in their local environment, and which are influenced by work culture, patients' interests, available technologies and expertise and institutional agenda. It has been shown that since patterns of clinical work practice vary significantly across work settings, sharing information and knowledge to support one another's clinical decision making across boundary becomes challenging in e-health because of the lack of contextual cues and practice-based knowledge, which are offered by a common work context, and which enables rich interaction in co-located settings. For cross-boundary practice transfer to be effective, researchers have argued that a certain degree of adaptation is required to achieve fit with users' local work environment.

This paper presents CaDHealth, a system to enable knowledge and work practice transfer among clinicians across geographical, regional and workplace boundaries for effective clinical decision support in e-health. The system offers a unifying structure that allows clinicians to make sense of clinical work situations across regional and workplace boundaries for effective e-health decision support. We hypothesize that the task of enabling context-aware decision support in cross-boundary e-health can be addressed, with acceptable results, through an understanding and a formal characterisation of contexts of work in various healthcare settings, and a specification of how context can be used, managed and transformed to suit various clinical problem solving situations. In particular, we highlight a number of user-informed design considerations, and describe the architecture and prototype of CaDHealth.

2. Related Work

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Designing systems for supporting clinical work practices and decision making is rooted in workplace studies of hospitals and healthcare practices in CSCW [8]–[10], and were influenced by long-term studies of human work in cognitive psychology and work design [18], activity theory [16], [15], , distributed cognition [72] and human-computer interaction [17] – from which two major lines of thought have, in the last two decades, emerged, namely the planned action model and the situated action theory [17]. The underlying argument is that while plan provides a pre-designed arrangement and the basis for the start of a work process, situated action, in tune with ad hoc and local contingencies, shapes how the given task actually gets accomplished.

One of the studies that have influenced this research work is the ethnographic study of 'Lawndale' practice by Gabbay and le May [8]. The authors argue that 'domain knowledge' [12] as employed by expert clinicians to 'technically' guide heuristics, pattern recognition or categorisation – 'illness scripts' [8] during diagnosis is not sufficient to account for the whole of range of issues and variables (e.g. lack of precision tools for early detection of breast lumps, or how to manage the psychological trauma of a bereaved patient) that a clinician has to deal with during diagnosis and treatment. The study notes that "clinical reasoning is far more situated and flexible than even the most complex clinical algorithm can express" [49], and introduced the concept of "clinical mindlines" [8] to describe the set of internalised, collectively reinforced and tacit guidelines, which are informed by clinicians' professional training, practical experience and their understanding of local circumstances and systems, and which serve as their "knowledge-in-practice-in-context" in dealing flexibly with the contingencies of clinical practice. Originating from the field of medical practice, study has brought to the fore the hitherto difficult to acknowledge fact that clinicians often do not strictly follow the "idealised model" of technical medical knowledge, but rather choose to draw, as circumstances warrant, from their clinical mindlines to address patients' needs in varying situations. Arguably, the outcome of the research has provided a fodder for the design of clinical decision support systems based on the correlation between local circumstances and patterns of clinical practice.

Recently, research findings, such as the aforementioned, have led to widespread application of context-aware computing techniques in the design of medical information systems. Bardram and Hansen [25] presented the concept of context-based workplace awareness aimed to investigate the use of context-awareness technique to facilitate workplace awareness. The work was based on an empirical study of coordination in surgical wards, and notes that awareness of spatial, social, temporal and activity context is important in hospital work coordination. Like other related studies, such as [14], [13], the focus is on the design of technologies to support workplace awareness in a manner that enables task coordination among staff working in the same hospital. Schmidt et al. [14], however, surmise that a possible approach would be to handle practices as malleable entities, noting that in spite of the significant variations in practices across work settings, studies have shown that healthcare work, whether co-located or spatially distributed, is intensely collaborative [19], [20]. This view resonates well with the findings of the user-centred study reported this paper that differences in clinical practice and decision making among clinicians across regional and geographical boundaries are, to a large extent, reconciled by adherence to best practice guidelines and the need to offer patient-centred care. The underlying design goal, therefore, would be to identify the areas of "commonalities" [14] and differences in practice patterns between two clinicians collaborating across boundaries.

Despite its strong role in explicating work processes in different contexts (e.g. in healthcare, see [8]), the concept of practice still attracts very little research attention as an approach to the design of information systems for decision and work process support. Mainly two research studies [22], [21], in HCI and information systems design as well as Patrick Brezillon's tremendous comparative analysis of practices and procedures in relation to the concept of contextual graph [23], have been found to consider the practice-based approach. Our study appears highly relevant in the face of emerging trends in knowledge networks and communities of practice, recent advances in e-collaboration and the increasing need among professionals in healthcare (and elsewhere) to harness globally distributed knowledge and leverage collective intelligence and social creativity across hospital, regional and workgroup boundaries for improved decision making [1], [2], [6] and, does have enormous implications for the design and adoption of future e-health technologies.

3. Design Considerations for Cross-Boundary Decision Support in E-Health

Boundaries of practice are a defining characteristic of hospitals and organisations [23], several research efforts, for example in information systems, have focused on the issue of boundaries as a way of

characterising resource use within particular communities and organisations.

Task domain: Boundaries of task domain accounts for the role of domain knowledge and principles in a work practice. It provides the underlying theoretical foundations for the task, and is what differentiates the task of a medical doctor from that of an accountant. Formal professional knowledge is crucial and highly emphasized in the medical profession, and as in any other field of knowledge work. It has been found out that the underlying essence of clinical work is identical across boundaries of work [14], and, as such, knowledge of task domain becomes crucial in understanding activities and tasks in any hospital.

Location and time of work and organisational factors: In our of clinical work practices, we often hear clinicians say "this is not compatible with hospital policy". Among UK clinicians, we often hear "what is NHS policy on this matter?" One clinician in Nigeria told one of the authors; "I will always explain my diagnostic and lab results very clearly to my patients because 'here' people will always take risks, even with their own health and do things their own way". The implication is that each workplace has a set of patterns or characteristics that are associated to it. Workplaces establish procedures based on their experience in order to guide reasoning and decision making in identified situations [23].

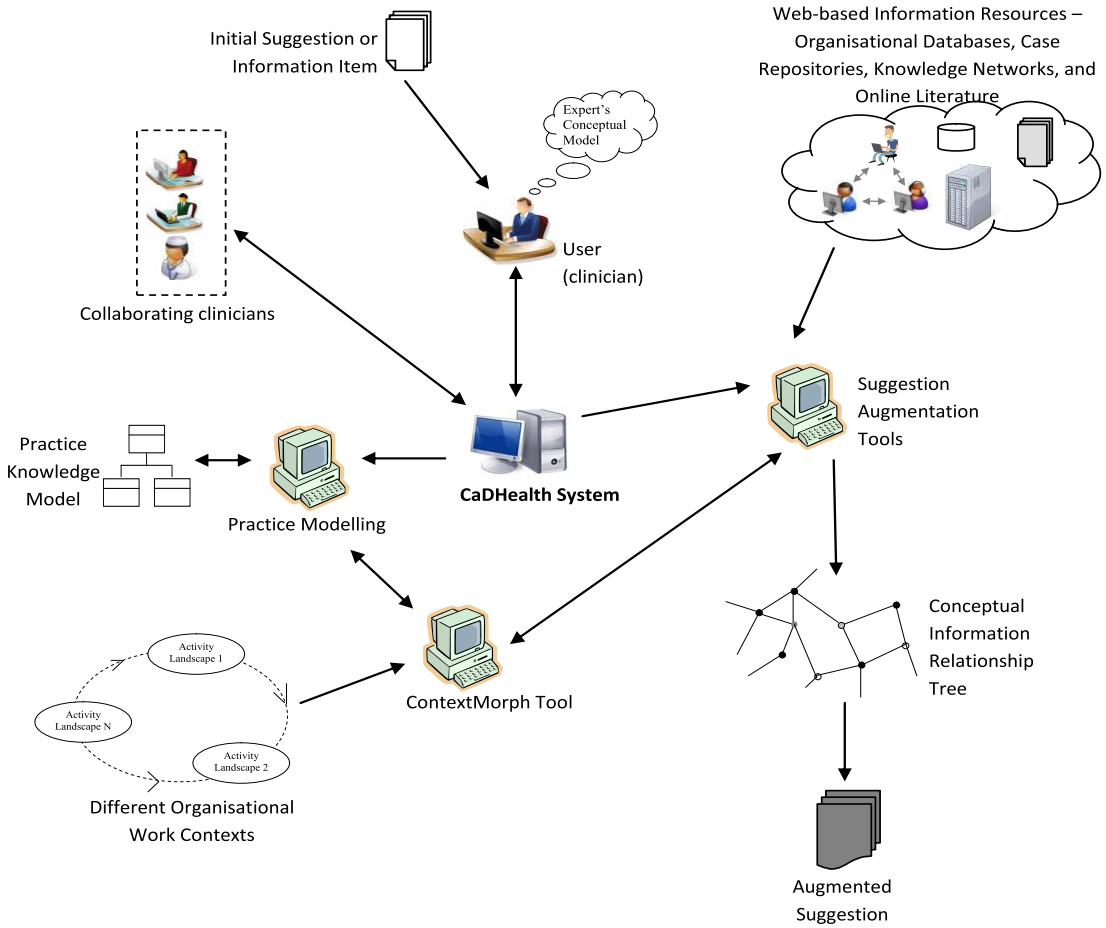

Figure 1. CaDHealth Architecture

Socio-cultural factors and institutional agenda: Similar to location and time of work and organisational factors, are socio-cultural factors institutional agenda. From the study, we found out socio-cultural factors and institutional agenda extend for longer periods of time and in most cases affect groups of hospitals in a particular regional. An example is the impact of NHS on the operations of hospitals in the UK. In the UK, the NHS defined regional boundary for clinical practice has made healthcare services cheap and affordable in the UK in contrast to countries like the US. As a result, a clinician in the UK prescribing for a low income earner patient would border less about drug cost than

he would in the US. In Nigeria, the same clinician would consider availability even before prescribing. In fact, the relationship between how a given task is planned to be carried out and how it actually gets done is an issue suffused with the socio-cultural properties of a workplace.

Personality and circumstantial factors: Despite the stereotype attached to a particular place and time, organisation or region, not every work process within the given place and time follows the stereotype. Those dynamically changing factors, such as a patient's changing ill health or economic condition, we refer to as situated factors and the practices they impact on as situated practices. On investigation, we found that situated practices have a correlation with the stereotypes and the local work context factors. As a result, we suggest that support for situated practices should be considered in the design of cross-boundary decision support systems.

4. Design of CaDHealth

Figure 1 presents the architecture of CaDHealth depicting how a user would access the system. CaDHealth is a prototype for practice-based **C**ross-bound**A**ry **D**ecision support in e-**Health**. The goal of CaHealth is to enable collaboration and practice-based information sharing among clinicians working across hospital and regional boundaries for the purpose of supporting one another's clinical decision for effective healthcare delivery. Figure 1 shows the three main subsystems, namely the work practice modeling, the ContextMorph and the suggestion augmentation components [4].

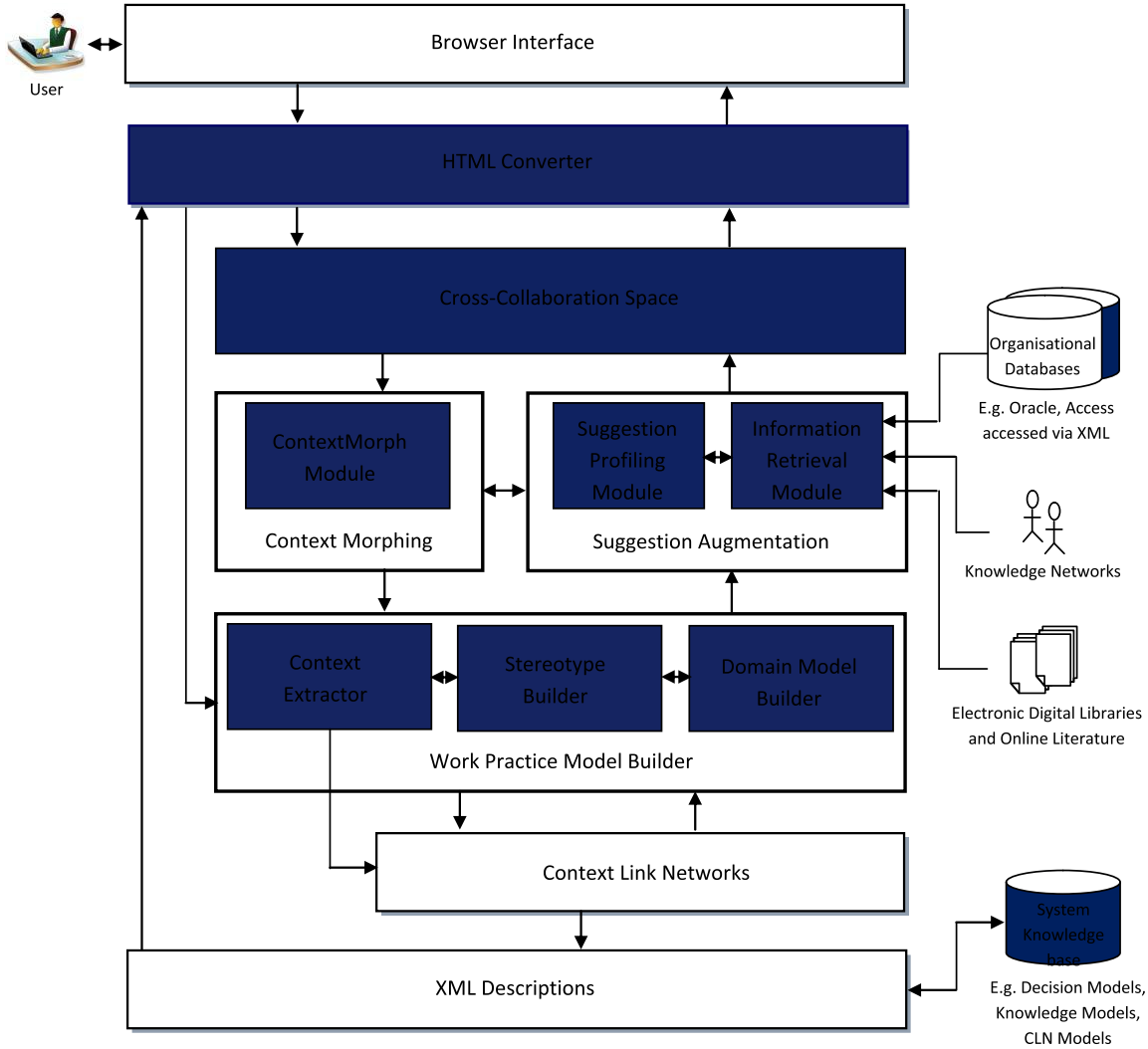

Figure 2: CaDHealth System Design

The work practice modelling component combines knowledge of the domain of work (e.g. breast cancer management) with context information about the hospital and the region (e.g. availability of secondary care specialists' services) as well as dynamic information about the given task (e.g. changing status of patient's ill health) in order to build models of work practice (see figure 1). The ContextMorph component is responsible for sharing practice information between user context and context of the suggestion provider with regard to the given task. The suggestion augmentation component retrieves more information from Web-based information sources (see figure 1) in order to enrich the suggestion provided to suite user context, and to justify or refute its use.

To access CaDHealth, consider a user, such as a clinician or a general practitioner (GP) who requires further information in order to carry out a task, and he has to seek expert opinion from outside of his workplace because, perhaps, experts are not available in his local workplace. The GP can either enter questions (as user query) to CaDHealth, or have the system automatically detect unresolved issues in his task specification based on known context information. The system has two major sources of information, namely models of work practice, which consists of system-generated work context information, and relevant information retrieved from the Web.

CaDHealth is designed as an advanced Web-based system, with secured access and an easy to use interface. Details of the underlying architectural design appear in [3], [4]. The design of Web-based clinical decision support system that ensures "appropriateness in medicine" by allowing clinicians access to online medical literature expert opinion has been proposed in [24].

5. CaDHealth Prototyping

In order to develop the CaDHealth prototype, we further decompose the three main system components in the architecture of CaDHealth into sub-components suitable for realisation in a prototype (see figure 2). The work practice modelling component consists of the domain model builder, the stereotype builder and the context extractor. The domain builder is responsible for generating concepts of a domain of work, e.g. concepts about breast cancer management [12]. The stereotype builders aggregates data about a workplace, i.e. the about the culture and known patterns of working in a place. The context extractor is responsible for extracting dynamically changing context data, i.e. the problem solving circumstances, about a given task. Work practice models of a set of workplaces (for a given task) are stored as context links network models. The suggestion augmentation module consists of the information retrieval and analysis module, which retrieves and analyses information from the Web and the suggestion profiler, which is responsible for scaling suggestions based on information about their providers. The ContextMorph component is responsible for transforming or matching suggestions based on the work practice information about two workplaces (where the suggestion originates and where the suggestion will be used).

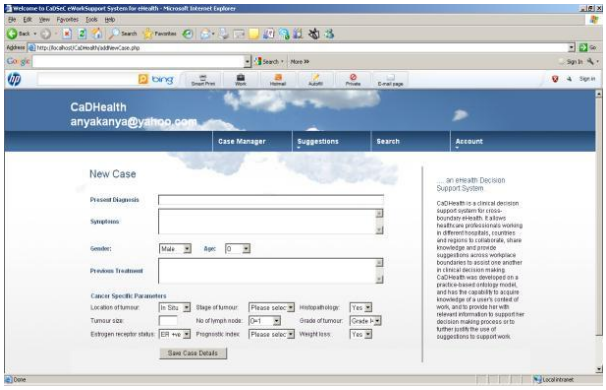

Figure 3: CaDHealth Example User Interface

The cross-collaboration space handles collaboration and interaction between tow users across boundaries. In CaDHealth, information is stored as XML descriptions in the system storage. Figure 3 show an example user interface of CaDHealth prototype.

6. Concluding Remarks

This paper presents CaDHealth, a system to enable knowledge and work practice transfer among clinicians across geographical, regional and workplace boundaries for effective clinical decision support in e-health. The system offers a unifying structure that allows clinicians to make sense of clinical work situations across regional and workplace boundaries for effective e-health decision support. We hypothesize that the task of enabling context-aware decision support in cross-boundary e-health can be addressed, with acceptable results, through an understanding and a formal

characterisation of contexts of work in various healthcare settings, and a specification of how context can be used, managed and transformed to suit various clinical problem solving situations. Future work will focus on deploying the system in a real world healthcare scenario for implementation and evaluation.

8. References

[1] Experts Group: New Collaborative Working Environments 2020, EUROPEAN COMMISSION Information Society Directorate-General, Report of the Experts Group on Collaboration @ Work, Brussels, Feb 2006

[2] N. I. Karacapilidis. E-Collaboration Support Systems Issues to be Addressed. Encyclopedia of Information Science and Technology (II) 2005: 939-945

[3] O. Anya, A. Nagar and H. Tawfik, A Conceptual Design of an Adaptive & Collaborative e-Work Environment, Proc. of 1st Asian Modelling Symp., Thailand, 27-30 March 2007.

[4] O. Anya, H. Tawfik, A. Nagar, S. Amin and K. Shaalan, Context-Aware Knowledge Modelling for Decision Support in E-Health, To appear in Proc of the E-Health Workshop, the IEEE Computational Intelligence, Spain, 18-23 July 2010

[5] R. Belotti, C. Decurtins, M. Grossniklaus, M. C. Norrie and A. Palinginis, Modelling Context for Information Environments, Ubiquitous Mobile Information and Collaboration Systems, Lecture Notes in Computer Science, Springer Berlin/Heidelberg, 3272, 2005, pp. 43-56.

[6] H. Zhuge, The Knowledge Grid, Singapore, World Scientific Publishing, 2004.

[7] N. Kock, (ed.) Encyclopedia of e-Collaboration, New York: IGI Global Publishers, 2008.

[8] J. Gabbay and A. le May, Practice-based Evidence for Healthcare, New York: Routledge, 2011.

[9] J. E. Bardram, A novel approach for creating activity-aware applications in a hospital environment, INTERACT '09, Springer-Verlag, 2009.

[10] J. E. Bardram, Activity-based computing for medical work in hospitals, ACM Transactions on Computer-Human Interaction, Vol. 16, No. 2, pp. 1–36, June 2009.

[11] B. Sari, H. Schaffers, K. Kristensen, H. Loh and R. Slagter, Collaborative Knowledge Workers: Web Tools and Workplace Paradigms Enabling Enterprise Collaboration 2.0, In ECOSPACE IP - eProfessional Collaborative Workspace, Dienstag, 2008.

[12] J. Angele and D. Fensel and R. Studer, Developing Knowledge-Based Systems with MIKE, Journal of Automated Software Engineering, 5, 1998, 389-418

[13] D. A. Mejia, J. Favela, A. L. Morán, Understanding and supporting lightweight communication in hospital work. IEEE Transactions on Information Technology in Biomedicine, Vol. 14, No. 1, pp. 140-146, 2010.

[14] K. Schmidt, I. Wagner and M. Tolar, Permutations of cooperative work practices: a study of two oncology clinics, Proceedings of the 2007 international ACM conference on Supporting group work, ACM, pp. 1–10, 2007.

[15] A. Kofod-petersen and J. Cassens, Activity Theory and Context-Awareness, Proceedings of the IJCAI-05 Workshop on Modeling and Retrieval of Context, pp. 1-12, 2005.

[16] Y. Engeström, R. Miettinen and R. Punamäki (eds.), Perspectives on Activity Theory (Learning in Doing: Social, Cognitive and Computational Perspectives), Cambridge University Press, 1999.

[17] L. Suchman, Plans and situated actions: The Problem of Human-Machine Communication, New York: Cambridge University Press, 1987.

[18] G. Z. Bedny and W. Karwowski, A Systemic-Structural Theory of Activity: Applications to Human Performance and Work Design. Boca Raton, CRC Press, Taylor and Francis, 2007.

[19] G. Ellingsen and E. Monteiro, A patchwork planet: Integration and cooperation in hospitals, Computer Supported Cooperative Work (CSCW): The Journal of Collaborative Computing, Vol. 12, No. 1, pp. 71-95, 2003.

[20] G. Fitzpatrick, Integrated care and the working record, Health Informatics Journal, Vol. 10, No. 4, pp. 291–302, 2004.

[21] L. Suchman, Practice-based design of information systems : notes from the hyperdeveloped world. The Information Society, Vol. 18, No. 2, pp. 139-144, 2002.

[22] K. Riemer an R. Haines, Pools and Streams: A Theory of Dynamic, Practice-Based Awareness Creation in Mediated-Communication, Proceedings of JAIS Theory Development Workshop, Sprouts: Working Papers on Information Systems, Vol. 8, No. 12, 2008.

[23] P. Brézillon, Representation of procedures and practices in contextual graphs, The Knowledge Engineering Review, Cambridge University Press, Vol. 18, pp. 147-174, 2003.

[24] C. Vanoirbeek, Y. A. Rekika, N. Karacapilidisa, O. Aboukhaleda, N. Ebela and J. -P. Vader, A web-based information and decision support system for appropriateness in medicine, Knowledge-Based Systems, Vol. 13, Issue 1, pp. 11-19, February 2000.

[25] J. E. Bardram and T. R. Hansen, Context-Based Workplace Awareness, Journal of Computer Supported Cooperative Work, Vol. 19, Issue 2, April 2010.