A Knowledge Management Framework to Operationalize Experiential Knowledge: Mapping Tacit Medical Knowledge with Explicit Practice Guidelines.

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Abstract: *Apart from traditional sources of medical knowledge found in the form of published evidence, other modality of knowledge like tacit form of knowledge is equally vital for clinical decision making. In this concept paper, we present a knowledge management framework which extracts tacit knowledge from past cases stored in a Case base and uses it with explicit knowledge stored in Clinical Practice Guidelines. The novelty of this model is that it uses the explicit knowledge acquired from scientific research in tandem with experiential knowledge found in past cases thus linking/mapping the two modalities of knowledge. Here we present the system design of the proposed work which will illustrate the functionality of the knowledge management framework.*

Keywords: *Knowledge Management, Clinical Practice Guidelines, Evidence-Based Medicine, Case-Based Reasoning, explicit knowledge, tacit knowledge.*

1. INTRODUCTION

The US Institute of Medicine reports that medical error annually results in between 44 and 98 thousand unnecessary deaths in the US and wastes up to $29Bn per annum. "Even using the lower estimate, more people die from medical mistakes each year than from highway accidents, breast cancer, or AIDS. Operational errors are not the only cause of avoidable adverse events but another important source is lack of knowledge of current best practice [1]". This report tells us that even the most professional and committed professionals cannot avoid gaps in the availability and flow of healthcare knowledge, or are unable to apply the available knowledge in the right way at the right time. This has significant consequences in terms of avoidable mortality, morbidity and the use of resources [2].

Traditionally, medicine is practiced based on anecdote, past experiences and domain authority. In 1992, a group of medical educators coined the new term- evidence-based medicine (EBM), and revamped the thinking about the evidential basis for clinical practice (The EBM working group, 1992). They argued that medicine should be evidence based to the extent possible that doctors should deliver care that is justified by scientific evidence, rather than by the traditional triad of anecdote, experience and authority [3]. The Information and Computer Technology age is no doubt changing the traditional practice of medicine; however it does not solve the medical knowledge overload crisis which gives rise to the gap between research and practice. However, empirical studies have shown that on an average, there is an 8-13 year time lag between treatment being proven to work and its practice. One of the major hurdles to this huge gap is the geometric growth of medical literature which is roughly said to double every 20 years [4] [5]. Thus, the recognition of this problem led to the movement of EBM to bring together practice and research. EBM focuses on synthesizing explicit knowledge in the form of research finding and applying it in clinical practice. EBM is a highly formalized form of explicit knowledge, however many regard EBM as not telling the whole story, that is putting greater emphasis on explicit modality of knowledge and undermining the importance of tacit knowledge. [6].

Hence recognizing the limitation of EBM to incorporate tacit knowledge, a knowledge mapping model which links the explicit and tacit modalities of knowledge is proposed. Explicit knowledge refers to the canonical form of knowledge found in the form of facts, rules, policies, in books, manuals etc. whereas tacit knowledge is the non-articulated, non canonical form of knowledge. Further, this paper investigates the possibilities and merits of mapping the explicit knowledge with tacit knowledge. Thus we argue that this novel idea should enhance the acceptability of the practice of EBM thus promoting its use further. The contention here is that CPG only provide explicit knowledge and a lot of tacit knowledge used in medical practice is not optimally utilized. To overcome this shortcoming, this knowledge mapping model proposes the use of CPG in tandem with tacit experiential knowledge stored in the form of structured cases in a CBR system. The technical architecture would comprise of existing medical language processing tools, CBR system architecture and few newly designed interfaces. Hence, a knowledge management solution is proposed here to map the explicit and tacit modalities of knowledge. Thus, in this paper, first we introduce the topics of Knowledge management, Evidence-Based Medicine, Clinical Practice guidelines, and Case-Based Reasoning. Then we describe the theoretical framework of the proposed knowledge mapping model followed by status of implementation and concluding remarks.

1.1 Medical Informatics

The topic of this research falls under the discipline of medical informatics or broadly referred to as Health Informatics. Medical informatics is a developing body of knowledge and a set of techniques concerning the organizational management of information in support of medical research, education, and patient care. Medical informatics combines medical science with several technologies and disciplines in the information and computer sciences and provides methodologies by which these can contribute to better use of the medical knowledge base and ultimately to better medical care [7].

The term *medical informatics* dates from the second half of the 1970s and was borrowed from the French expression *informatique médicale*. Before that time, other names were used (and are sometimes still in use), such as *medical computer science*, *medical information science*, *computers in medicine*, and more specialized terms such as *nursing informatics*, *dental informatics*, and so on. These terms have their parallels with similar ones in areas outside health care, such as *computer science*, i*nformation processing*, and in specialized areas, for instance: *computational physics*, *computational linguistics*, or *artificial intelligence* [8]. Medical informatics workers originate from various disciplines including medicine and computer, library or cognitive sciences. According to Enrico Coiera, "Medical informatics is as much about computers as cardiology is about stethoscopes [9]." It has been said that, the study of informatics in this century will probably be as fundamental to the practice of medicine as the study of anatomy has been to the past century [10]. Figure 1 below illustrates the relationship between MI and other disciplines.

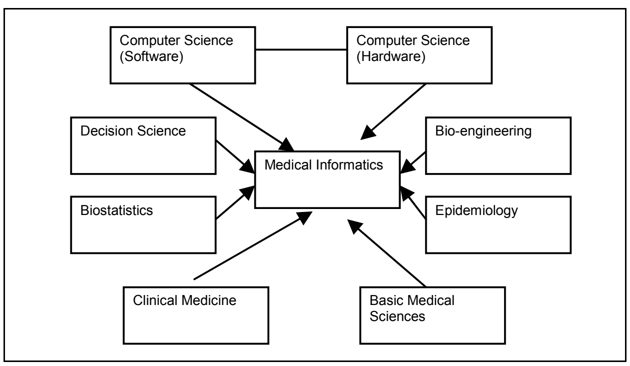

Figure 1: MI and its related disciplines.

The role of the information sciences in medicine continues to grow, and the past few years have seen informatics begin to move into the mainstream of clinical practice. Informatics finds application in the design of decision support systems for practitioners, in the development of computer tools for research and in the study of the very essence of medicine--its corpus of knowledge [11] [12] [13].

1.2 Knowledge Management

Knowledge Management (KM) concerns the gathering, organization, refinement and distribution of knowledge. Knowledge is the most critical resource in provision of health care; access to the latest medical research can mean a world of difference, at times, even between life and death. Before we dig deep into the concepts of knowledge management, let us try to understand as to what is knowledge. The key terms: data, information, and knowledge need to be defined. Data forms the base of the hierarchy of meaning [14]. Data represents numbers or objects only when provided with context does it have any meaning. For example, "Cholesterol 5.4 mmol" is just a piece of data, however, it gains significance when contextualized by the additional information that this patient has heart disease, thus informing the clinician that this patient may benefit from a cholesterol lowering drug. Information may also be considered to be a flow of messages [15] for example; a series of cholesterol recordings may inform the clinician as to the effectiveness of diet or therapy. Passing data through a "sense-giving interpretative framework" to produce information is a further way of describing this process [16]. What differentiates knowledge from information is that knowledge is conditional on the existence of commitment and belief that something is right or true. Information is akin to data corroboration.

In other words, knowledge is considered to be a higher form of information that can be used for decision making. This relationship between data, information, and knowledge is illustrated in figure 2 below.

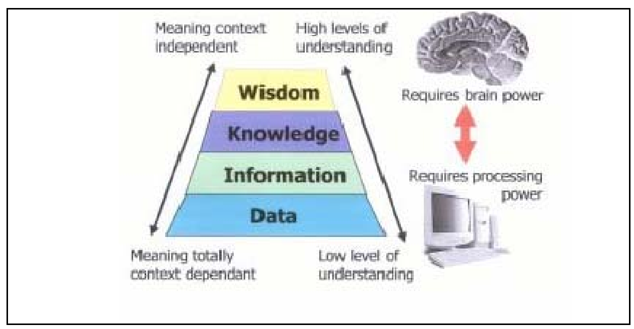

Figure 2: Hierarchy of understanding [14]

The main distinguishing factor between knowledge and information and data for that matter is that knowledge is intellectually intensive rather than IT-intensive which is produced as a result of human interpretation and analysis as opposed to data processing [15][16][17].

Knowledge can be classified mainly into two categories: Tacit knowledge and Explicit knowledge [18]. Tacit knowledge is the higher form; it is the non-articulated, non canonical knowledge. Explicit knowledge on the other hand is the more familiar canonical form of knowledge found in the form of facts, rules, policies, in books, manuals etc. By combining qualitative and quantitative approaches, the short comings of both strategies can be offset, validity of clinical evidence can be strengthened by qualitative and quantitative methods, thus both complement each other. The tacit and practical knowledge in clinical practice is referred to as the art of medicine as being the opposite of science of medicine [19].

1.2 Evidence-Based Medicine

David Sackett's definition is widely used as the basis for pedagogy in evidence-based medicine. He defined evidence-based medicine as *"the conscientious, explicit and judicious use of current best evidence in making decisions about the care or individual patients"* [20].However, a strong criticism of EBM is that it takes away the art from medical practice and overemphasizes the importance of scientific research. Within medicine, emphasis has been placed on formalized explicit knowledge [21]. Engel recognized that physicians can't manage their patients simply as biomedical models [22], and that there is often another dimension to disease and patient- management. The failure to recognize the limitations of EBM leads to tension being created when it cannot be implemented [23]. Clinicians often lack a language with which to communicate important knowledge, for which there is no high-grade evidence base [24]. The main objective of this research is to address this shortcoming. Table 1 below shows a continuum of evidence as to how levels of evidence vary based on its source.

Table 1: A Continuum of Evidence

Continuum of Evidence					
Qualitative				Quantitative	
Opinion based on experience	Descriptive studies	Surveys	Cohort studies	Non-randomized Trials	Randomized Controlled Trials

1.3 Clinical Practice Guidelines

Clinical Practice Guidelines (CPG) are systematically prepared statement to help the physician with best decision making with regards to a certain medical condition [25]. CPG are prepared after rigorous scientific research conducted through randomized clinical trials etc. The knowledge contained in CPG is strictly explicit and in accordance with the belief that it advocates the practice of evidence based medicine [26]. These guidelines, which are also synonymously referred to as Evidence-Based Guidelines, are textual in nature. Lately, a lot of interest has been shown to computerize these guidelines so that they can be used at point-of-care in the form of diagnostic and therapeutic decision support systems. A number of CPG representation models have been proposed by researchers and have also been successfully deployed. There are various guideline representation models which include the Arden Syntax, the Asbru model, the EON model, the GLIF model, the PROforma model, the GUIDE model, the GASTON mode, the GEM model etc [27]. For our framework, we use the Guideline Element model (GEM).

1.4 Case-Based Reasoning

Case Based Reasoning (CBR) is a problem solving paradigm that is in many respects different from other major AI approaches. Instead of relying only on general knowledge of a problem domain, CBR is able to use the specific knowledge of past experience. Hence a new problem is solved by finding a similar past case and reusing it in a new problem situation. A second important difference is that CBR also is an approach to incremental, sustained learning, since a new experience is retained each time a problem has been solved, making it immediately available for future problems. The CBR field has grown rapidly over the last few years, as seen by its increased share of papers at major conferences, available commercial tools, and successful applications in daily use [28]. At the highest level of generality, a CBR cycle may be illustrated by figure 3 [28].

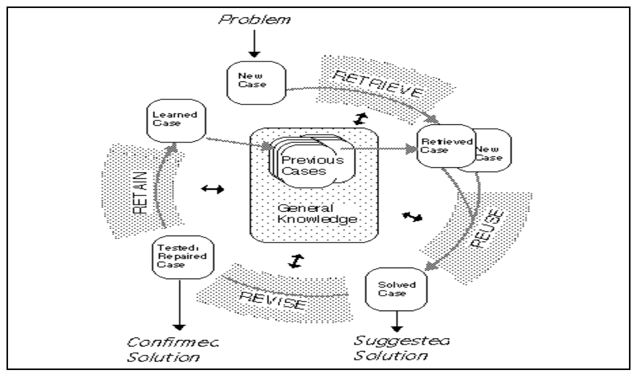

Figure 3: The CBR Cycle [28]

2. THEORATICAL FRAMEWORK OF PROPOSED KNOWLEDGE MAPPING MODEL

The concept proposed here is the mapping of explicit form of knowledge with tacit form of knowledge. The objective of this model is that explicit knowledge in the form of CPG is enriched by tacit, experiential knowledge found in the form of documented experience. The rational for doing this is to supplement one form of knowledge with the other. Each experience is represented as a case using a structured CBR approach. Knowledge is extracted from CPG using Natural language processing tools and domain ontology because text in the CPG will be used to form queries for the CBR system. The experiential knowledge is stored in a case base which takes as input queries formulated earlier from the CPG. This idea was conceived after getting inspired from Abidi et al work on the BiRD System. [30].

To achieve the above functionality, we present the design of the proposed work divided into following tasks (the implementation details are beyond the scope of this paper):

2.1 Operationalization of Explicit Knowledge

Working with a textual CPG, we first convert it into computerized CPG (for our model we use GEM which is an XML-based guideline document model). GEM, was developed at the Yale Center for Medical Informatics, and is downloadable for research purposes only from www.ycmi.med.yale.edu/gem/

Figure 4 shows part of textual CPG taken from National Guideline Clearinghouse [www.guideline.gov] which is a public resource for evidence-based clinical practice guidelines. NGC is an initiative of the Agency for Healthcare Research and Quality(AHRQ), U.S. department of Health and Human Services. The guideline selected for use here is the evidence-based guideline for weaning and discontinuation of ventilaory support. Further guideline details can be looked up at www.rcjournal.com/online_resources/cpgs/ebgwdscpg.asp

GUIDELINE TITLE

Evidence-based guidelines for weaning and discontinuation of ventilatory support.

Recommendation 1. In patients requiring mechanical ventilation for > 24 hours, a search for all the causes that may be contributing to ventilator dependence should be undertaken. This is particularly true in the patient who has failed attempts at withdrawing the mechanical ventilator. Reversing all possible ventilatory and non ventilatory issues should be an integral part of the ventilator discontinuation process.

Figure 4: Part of sample textual CPG

Since there is a need to identify the terms in the medical vocabulary and its relationships, a reference to standardized domain vocabulary needs to be made. For this purpose we use a controlled medical vocabulary MeSH(Medical Subject Headings) terms using the MMTx – Meta Map Transfer tool developed by the National Library of Medicine (NLM). This tool offers the functionality to translate plain text to meaningful MeSH terms [http://www.nlm.nih.gov]. In essence, its purpose is to link alternative names and views of the same concept together and to identify useful relationships between different concepts. The MMTx program takes as input sentence and separates it into phrases, identifies the medical concepts and assigns proper semantic categories to them according to knowledge embedded in UMLS. The output of MMTx would give us the MeSH terms derived from the C-CPG content together with UMLS semantic types (the output options can be set in such a way to produce semantic along with MeSH terms). Figure 5 is the screen dump of the runtime session of MMTx which shows the execution of program. With this software, text is taken through a series of modules and broken down into the components that include sections, sentences, phrases, lexical elements and tokens. Candidate concepts from the UMLS Metathesaurus are retrieved and evaluated against the noun phrase and their derivatives. The best of the candidate are one result. The resulting concepts are organized in such a way as to best cover the text, known as final mapping.

```
# java programs.MMTx
About to set the output file to standard output
MMTX (2001)

Control options:
        best_mappings_only
        plain_syntax
        mappings
        semantic_types
Using Database: DB_01_strict
       Obstructive Sleep Apnea
       Processing 00000000.tx.0: Obstructive Sleep Apnea
       Phrase: "Obstructive Sleep Apnea"
       Meta Candidates (7)
         1000 Sleep Apnea, Obstructive [Disease or Syndrome]
          901 Apnea, Sleep (Sleep Apnea Syndromes) [Disease or Syndrome]
          827 Apnea [Pathologic Function, Sign or Symptom]
          827 Obstructive (Obstructed) [Functional Concept]
          827 Sleep [Mental Process]
          755 Sleeplessness [Disease or Syndrome,Sign or Symptom]
          755 Sleepy [Finding]
        Meta Mapping (1000)
         1000 Sleep Apnea, Obstructive [Disease or Syndrome]
```

Figure 5: Example of MMTx program running from standard input and producing standard output.

In this example, the phrase "Obstructive Sleep Apnea" is parsed through MMTx and the processed output shows the recognition of token matched with MeSH terms and the associated semantic types. The matched MeSH terms are "sleep,", "apnea,", and "obstructive" and the semantic types associated are "finding,", "disease,", "syndrome" etc. This illustration is simply given here to show the working of MMTx software. For our purposes, we will feed part of the CPG to MMTx and then with the help of generated MeSH terms and associated semantic type, generate queries that are later fed to the CBR system.

All these tools are downloadable from the UMLS Knowledge Servers found at NLMs website which are made available for research purposes only. The purpose of NLM's Unified Medical Language System® (UMLS®) is to facilitate the development of computer systems that behave as if they "understand" the meaning of the language of biomedicine and health. By design, the UMLS Knowledge Sources are multi-purpose. There are three UMLS Knowledge Sources: the Metathesaurus®, the Semantic Network, and the SPECIALIST lexicon.The Metathesaurus is a very large, multi-purpose, and multi-lingual vocabulary database that contains information about biomedical and health related concepts, their various names, and the relationships among them [www.mmtx.nlm.gov/].

In essence, what we have done so far is to process the explicit knowledge in CPG and prepare it to be mapped with the tacit knowledge found in past cases. Next we will work towards operationalizing the tacit knowledge and preparing it to be linked to the explicit modality of knowledge.

2.2 Operationalization of Tacit Knowledge

Tacit experiential knowledge found in the form of past cases is structured and stored in a case-base. The queries passed from our explicit side of the model finds its way into the CBR system and looks up for optimal solution; if the cases don't match to the extent desired, then case adaptation will take place using any of the widely known adaptation techniques. A sample case is shown in figure 6.

For the proposed model, two case representation schemes will be investigated. Cases could either be structured as scenarios using object oriented structures as presented by Abidi et al [31] or cases could be represented using Case-Based Markup Language(CBML) and then mapped with the XML-based Gem encoded CPG using some mapping algorithm for example support vector model or CBR similarity measurement model [32].

2.3 Mapping Explicit Knowledge with Tacit Knowledge

This is the part where the art of practice meets the science of practice; that is the research evidence found in the form of clinical practice guidelines is mapped and linked with the tacit knowledge in the form of experiential knowledge in found in the past cases, stored in a case-base. Assuming, at this point after identifying the form and format of tacit knowledge, a suitable case representation structure has been designed. Now from the CPG a way of mapping which is either in the form of a query or in general a mapping algorithm will be used to link up to the CBR system and produce optimal solutions for recommendation at hand. Thus the complete working could be understood by figure 7 given below which explains 1) the operationalization of explicit knowledge, 2) operationalization of tacit knowledge, and 3) finally linking the two types of knowledge.

2.4 Role Of The Domain Expert

For this research, a domain expert is working with us to provide assistance in the following tasks:

- ✓ Provide us with past cases to populate the case base.
- ✓ Help us identify/understand the tacit knowledge in the cases.
- ✓ Validating the computerized CPG.
- ✓ When C-CPG is parsed, validate the MeSH terms and semantic types.
- ✓ Evaluate the working of the system.

62 year old black male brought to ER by EMS. Pt notes worsening shortness of breath for 2 days not responding to nebs. Not responding to MDI at home. C/O fever/chills and cough productive of yellowish sputum. One albuterol/atrovent neb given in field with little to no change

PMHx: COPD X 10 yrs(chronic obstructed pulmonary disease), GERD X 3 yrs(gastroesophageal reflux disease)
No prior history of intubation
PSHx: Appendectomy
Meds: albuterol inhaler, atrovent inhaler, advair diskus

Vitals:
BP 180/110, Heart rate: 130's, Resp rate: 32, Temp 100F
…..
Pt is intubated in ER for hypercapnic, hypoxemic resp failure with size # 8 ETT (endotracheal tube) and admitted to MICU.

Day # 2
Sedation decreased
vent changes Mode SIMV/PS. FIO2 decreased to 55%, RR 12, VT 600, peep 5
Pt's HR 100, BP 140/85, spont resp rate 20 on a set rate of 12
Failed SBT

Day # 3
Pt off sedation, SBT (spont breathing trials)
ABG: 7.34/48/84/27 on Fio2 35%, peep 5, VT 600, PS 10
RSBI (rapid shallow breathing index = RR/VT in liters)
Pt's parameters on vent on SBT, RR= 22, spont tidal vol= 500, RSBI= 22/.5= 44
In addition BP, HR stable, Pt is awake alert (RSBI's <100 are shown to have successful weaning off the vent)
Pt is extubated successfully and DC'd home on day 7.

Figure 6: A sample case

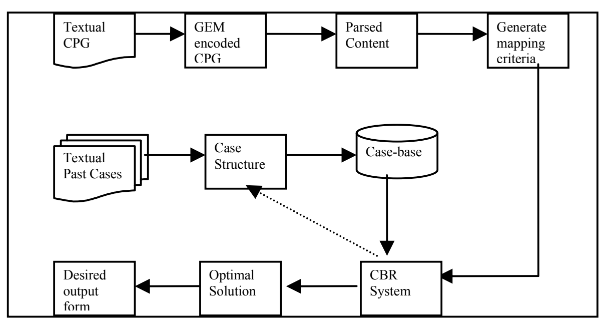

Figure 7: The Functional Overview of the presented model

3. CONCLUSIONS AND FUTURE WORK

In our endeavor, we are currently computerizing the CPG to make it ready to pass through parsing phase, then, queries or some mapping algorithm will be used to link up the CPG with experiential knowledge.

On the other hand, past cases are being thoroughly studied to identify the kind of tacit knowledge which will be required and then structured in order to be stored in the case-base. The representation of the cases is still under design phase. Evaluation of the system will be done with the help of the domain expert. It would in the end present a working proof-of-concept which will demonstrate how to link evidence with experience. We feel that this approach will increase the acceptance of CPG in the medical community and in turn increase acceptance of EBM.

ACKNOWLEDGEMENTS

We would like to thank Dr. Syed Sibte Raza Abidi who plays an instrumental role in this project and without whom this work would not have been possible. Dr Abidi is with the Faculty of Computer Science, Dalhousie University, Halifax, NS, Canada. We would also like to extend our appreciation to Dr. Rubina Kerawala who is the domain expert for our project. Dr. Kerawala is a fellow in pulmonary and critical care medicine and is currently associated with the Baylor College of Medicine, University of Texas, U.S.A.

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