Medical Knowledge Morphing: Towards Case-Specific Integration of Heterogeneous Medical Knowledge Resources

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Abstract

Clinical decision-making involves an active interplay between various medical knowledge modalities—the spectrum of medical knowledge modalities spanning from tacit knowledge to experiential knowledge to explicit knowledge to data-induced knowledge. The ability to simultaneously access and then integrate multiple knowledge modalities pertaining to a common clinical theme is profound for clinical decision making. In this concept paper we introduce knowledge morphing—a knowledge modeling task that allows the integration of heterogeneous medical knowledge modalities, with respect to a clinical case, to yield a comprehensive knowledge resource for decision-support.

1. Introduction

Clinical decision-making involves an active interplay between various medical knowledge modalities—the spectrum of medical knowledge modalities spanning from tacit knowledge to experiential knowledge to explicit knowledge to data-induced knowledge [1-4]. More specifically, in a medical context the different knowledge modalities can be identified as (a) the tacit knowledge of practitioner in terms of problem-solving skills, judgment and intuition; (b) clinical experiences (both recorded and observed) and lessons learnt; (c) collaborative problem-solving discussions or consultations between practitioners; (d) published medical literature and clinical practice guidelines; (e) operational knowledge in terms of clinical protocols and pathways; (f) medical education content for practitioners; (g) patient education content; (h) formal decision support knowledge encapsulated as symbolic decision rules obtained from domain experts and/or decision models induced from data; (i) social networks eliciting members of a community of practice and their communication patterns, interests and maybe even expertise; and (j) data-mediated knowledge based on data of clinical observations, diagnostic tests and therapeutic treatments, recorded in medical records and stored in a clinical data-warehouse.

Prevailing medical knowledge management initiatives address the creation, collection, sharing and operationalization of a single medical knowledge modality [5-7]. However, from a pragmatic decision-support point of view, medical practitioners need comprehensive, contextually-relevant knowledge that is both congruent with the evolution of the patient and at an appropriate level of abstraction. The provision of holistic case-specific medical knowledge—in keeping with the large volume and diverse modalities of medical knowledge—is a challenging task because it not just involves the timely and relevant retrieval of diverse medical knowledge objects but also the *morphing*, via the seamless fusion or integration, of heterogeneous medical knowledge modalities into a unified case-specific problem-solving knowledge resource. More so, the morphing of medical knowledge involves the integration of one form of

knowledge—say tacit clinical judgments—to another knowledge modality—say explicit clinical practice guidelines based on a common theme/topic (see figure 1).

The ability to simultaneously access and integrate multiple knowledge modalities pertaining to a common clinical theme is profound for clinical decision making. The importance of integrating multiple knowledge modalities is amplified by the fact that clinicians need to provide advice in many situations where strong evidence is lacking and therefore they are required to source, appraise and synthesize different knowledge modalities to arrive at an informed conclusion. For instance, in the absence of explicit clinical algorithms based on scientific evidence, practitioners may need to refer to tacit modalities of medical knowledge, such as clinical experiences of their peers and/or the clinical acumen and expertise of domain experts recorded as problem-solving scenarios [7]. It is our contention that, it is in these situations that the morphing of heterogeneous knowledge modalities may provide an overall view to practitioners of what solution will work, why it will work, and how to make it work. In this concept paper we will introduce *knowledge morphing*—a knowledge modeling task that allows the integration of heterogeneous medical knowledge modalities with respect to a clinical case (shown in figure 1) [8]. Also we will demonstrate exemplar knowledge morphing applications.

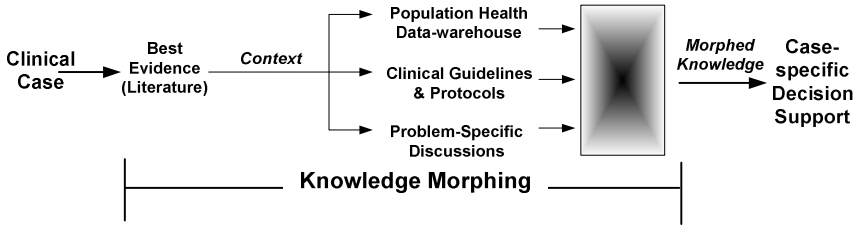

Figure 1: A conceptual overview of medical knowledge morphing

2. Knowledge morphing

At a cognitive level, medical practitioners 'intrinsically' determine the function, objectivity, need and correlation between the different and distributed medical knowledge objects, despite them being represented in different modalities. Likewise, in practice medical practitioners synthesize and operationalize medical knowledge, from different sources, in a methodological, seamless, continuous and interchangeable manner as per the demands of the clinical problem at hand [9]. From a systemic perspective, one can then argue that the process of solving a clinical case essentially entails a seamless 'fusion' of heterogeneous medical knowledge depending on the clinical context and the knowledge needs of the user. Throughout the evolution of the patient, the origin of the overall medical knowledge that is applied is not necessarily from a single modality or source, rather it dynamically originates through the seamless 'morphing' of existing medical knowledge from one modality to another given the nature of the clinical context and objectives; and through this knowledge morphing process the evolving knowledge is enriched with different, yet useful, perspectives.

We introduce the concept of *knowledge morphing* as "the intelligent and autonomous fusion/integration of contextually, conceptually and functionally related knowledge objects that may exist in different representation modalities and formalisms, in order to establish a comprehensive, multi-faceted and networked view of all knowledge pertaining to a domain-specific problem". Knowledge morphing is deemed as a complex modeling activity that interpolates a knowledge link between two or more knowledge objects that share a discrete notion of contextual compatibility. The knowledge link, which is an abstraction specified at a level suitable to the user, allows

reasonable inferencing over the original knowledge instances in order to derive a more comprehensive and enriched knowledge resource. The process of knowledge morphing is very much context dependent, where the contexts accommodate a wide range of situations as the *problem-solution* space over which knowledge instances can be morphed with each other.

We believe that for medical decision-support, knowledge morphing is highly pertinent due to the existence of multiple medical knowledge modalities and the corresponding need to integrate these modalities based on the patient's case to acquire a comprehensive understanding of all available solutions, viewpoints and documented outcomes. There exist knowledge gaps between guidelines and real practice, instruction and practice, and experience and evidence. One way to address these knowledge gaps is to enable practitioners to juxtapose various knowledge sources—i.e. to morph knowledge from different sources, based on contextual compatibility, in order to provide multi-dimensional case-specific knowledge that includes guidelines, experiences, evidence and so on (shown in figure 2).

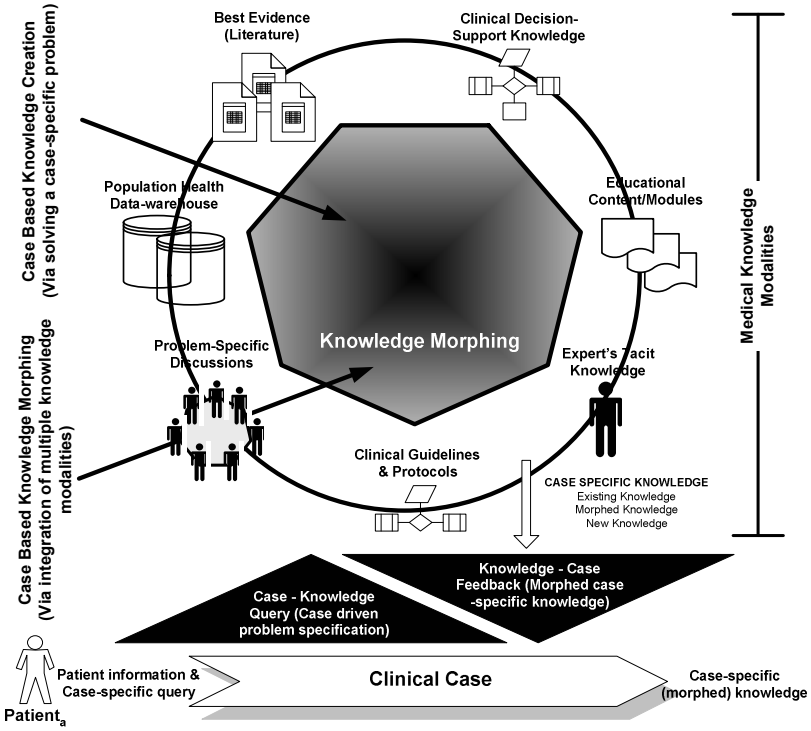

Figure 2: A medical knowledge morphing framework.

Currently, the manual retrieval and integration of heterogeneous and distributed medical knowledge for a specific clinical case is not only tedious but the task is constrained by the subjective nature of the queries posed by the user to different knowledge resources [8]. The problem is further compounded by the practitioner's general lack of understanding of (i) both the existence and usability of the heterogeneous knowledge resources; (ii) variations in the conceptual model and terminology used by heterogeneous knowledge sources; (iii) an optimal query specification strategy that allows the generation of complex queries for simultaneous access to multiple knowledge resources; and (iv) methods to combine the results from multiple knowledge resources. Querying distributed knowledge resources is a non-

trivial task as it involves complex steps such as deciding which knowledge resource to use and in which order, how concepts in one knowledge resource links to concepts in other knowledge resources, and how to integrate the results whilst maintaining constraints for relevance, compatibility and logical cohesion.

Our proposed knowledge morphing framework, attempts to alleviate the above knowledge retrieval problems by assisting practitioners seeking case-specific knowledge to formulate a single semantically rich knowledge query that is applied to multiple knowledge resources. Next, the knowledge retrieved from distributed sources is subjected to internal reasoning, transformation and critiquing leading to its integration as a single morphed knowledge object. The morphed knowledge object can then be used by a practitioner either to reason for decision support or to compare variations between best and real practice or between practitioners.

3. Knowledge Morphing Exemplar Applications

3.1. Knowledge Morphing: Tacit knowledge to medical literature

This knowledge morphing application provides a mapping between the tacit and experiential knowledge inherent within online problem-specific discussions to (a) corresponding explicit knowledge at PubMed; and (b) a social network depicting a community of paediatric pain practitioners based on their interest and expertise [10].

The tacit and experiential knowledge of a community of pediatric pain practitioners is captured through email-based communication via a discussion forum—named Pediatric Pain Discussion List (PPDL). PPDL reflects the problem-specific tacit knowledge and clinical experience of pediatric pain specialists, which might not otherwise be shared or made explicit via published medical literature. The efficacy of knowledge morphing is realized when practitioners need to (i) either validate or to get further evidence about any advice/support provided to them through PPDL; and (ii) verify or seek the opinion of their peers with respect to the veracity, practicality and impact of research findings presented in medical literature. Our knowledge morphing strategy involves three main KM stages (see figure 3).

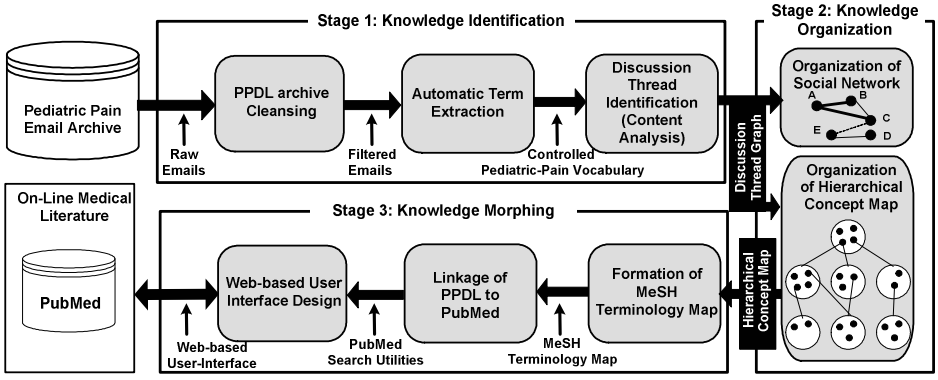

Figure 3. Knowledge Morphing—tacit knowledge to medical literature & community of practice

Stage 1 involves the identification of problem-mediated and topic-specific *discussion threads* comprising a continuous sequence of individual email messages. Stage 2: involves (a) the formation of a hierarchical *concept map* that represents clusters of contextually similar discussion threads; and (b) the identification of *social networks* depicting the interactions between PPDL contributors during various discussions. Here, both the concept map and the social network serve as a high-level abstraction of the

knowledge and establish the knowledge link for knowledge morphing. Stage 3 establishes knowledge linkages between the concept map with online medical literature at PubMed. In practice, users can find corresponding literature for a topic-specific discussion, and in reverse users can link to peer discussions related to an article.

3.2. Knowledge Morphing: Clinical Cases to Clinical Practice Guidelines

In this knowledge morphing application we establish bi-directional knowledge links between tacit knowledge captured in terms of solved clinical cases (represented in a case-based reasoning formalism) and explicit knowledge in terms of computerized clinical practice guidelines. The efficacy of the application is realized in situations when practitioners seek insights from past experiences and outcomes for similar current cases, and then to relate their findings/inferences/judgments to corresponding clinical practice guidelines or vice versa. Our knowledge morphing strategy in illustrated in figure 4.

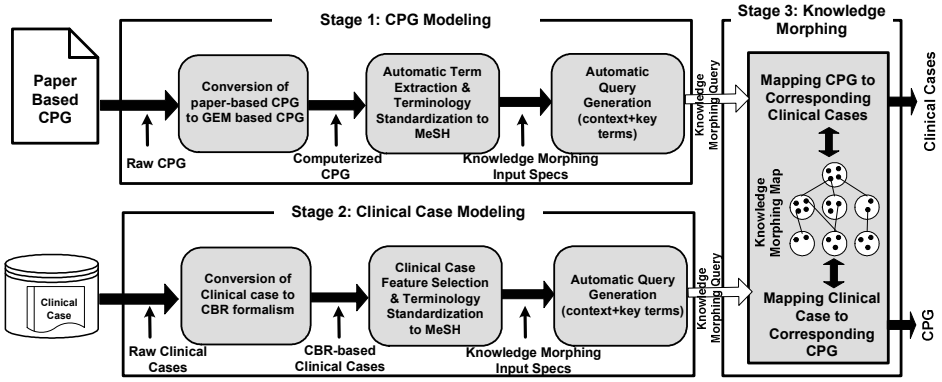

Figure 4: Knowledge Morphing—CBR cases and CPG

3.3. Knowledge Morphing: Clinical Cases to Clinical Practice Guidelines

This knowledge morphing application allows for the fusion of two explicit knowledge resources—i.e. computerized clinical practice guidelines with corresponding medical literature at MEDLINE [11].

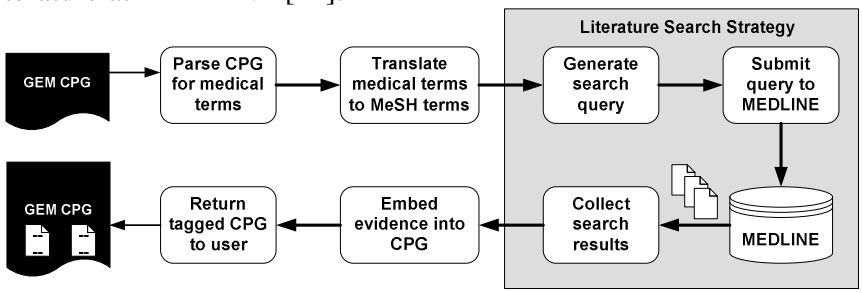

Figure 5. Knowledge Morphing—CPG and medical literature

The utility of knowledge morphing is amplified when practitioners need best evidence in concert with a computerized CPG. In this situation, our knowledge morphing application asks the practitioner to specify the CPG content for which evidence is sought. Then, in an autonomous and user-transparent manner, an optimal search query is formulated based on the specified CPG content, the query is submitted to MEDLINE to retrieve the evidence (as articles); and the retrieved evidence is finally morphed with the corresponding CPG content. A web-enabled *Best-evidence Retrieval and Delivery* (BiRD) system provides the knowledge morphing linkages by

implementing a multi-level context-sensitive medical literature search strategy that is based on automatic query generation from the CPG content (figure 5).

4. The Way Ahead: Semantic Web and Knowledge Morphing

The exemplar knowledge morphing applications, at present, are using different conceptual methods to establish the knowledge links between heterogeneous knowledge elements. Our aim is to create a semantic web of the knowledge resources, whereby the knowledge contents of each knowledge resource are conceptually identified and semantically annotated based on (a) global domain ontology and (b) local knowledge resource ontology. We anticipate the semantic web approach will realize high-level and dynamic semantic links between heterogeneous knowledge modalities, and allow for the morphing of knowledge from one modality to another. Furthermore, via the domain ontology and inter-ontology view integration we plan to integrate the underlying conceptual schemas of the knowledge resources into a global schema which can be queried by a semantically-qualified high-level query language for the retrieval of contextually-similar knowledge elements from different knowledge resources.

In conclusion, we argue that once completed our medical knowledge morphing solution will allow for a transparent and integrated way to query the multiple knowledge resources with respect to a patient's case.

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