Intelligent Healthcare Information Assistant: Towards Agent-Based Healthcare Knowledge Management

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Abstract. Initiatives in healthcare knowledge management have provided some interesting solutions for the implementation of large-scale information repositories vis-à-vis the implementation of Healthcare Enterprise Memories (HEM). In this paper, we present an agent-based Intelligent Healthcare Information Assistant (IHIA) for dynamic information gathering, filtering and adaptation from a HEM comprising an amalgamation of (i) databases storing empirical knowledge, (ii) case-bases storing experiential knowledge, (iii) scenario-bases storing tacit knowledge and (iv) document-bases storing explicit knowledge. The featured work leverages intelligent agents and medical ontologies for autonomous HEM-wide navigation, approximate content matching, inter- and intra-repositories content correlation and information adaptation to meet the user’s information request. We anticipate that the use of IHIA will empower healthcare stakeholders to actively communicate with an ‘information/knowledge-rich’ HEM and will be able to retrieve with ease ‘useful’ task-specific information via the presentation of cognitively intuitive queries.

1. Introduction

The healthcare domain is indeed overwhelmed with a wide spectrum of information being collected from a multitude of sources. And, we note with interest many concerted research efforts in medical informatics focusing on the ‘efficient’ storage of such large volumes of healthcare information [1]. Initiatives in healthcare knowledge management have indeed provided some interesting solutions vis-à-vis the implementation of Healthcare Enterprise/Organizational Memories (HEM) that may ontologically classify and store the different types of healthcare information/knowledge in functionally divergent repositories that co-ordinate for all intents and purposes within the unified framework of an enterprise/organizational memory [2][3]. Despite the organizational efficacy of HEM, there are concerns regarding the ‘retrievability’ of stored information, in particular by novice users as they are expected to be familiar with the query structure and semantics, source and type of information and description of information context pertaining to the information sought.

In this paper, we present an agent-based solution to the above information retrieval constraints via the implementation of an agent-based Intelligent Healthcare Information Assistant (IHIA). The IHIA is a client-server info-structure that features autonomous information gathering, filtering and adaptation from a HEM comprising an amalgamation of (i) databases storing empirical knowledge, (ii) case-bases storing experiential knowledge [4], (iii) scenario-bases storing tacit knowledge [5] and (iv) document-bases storing explicit
knowledge. Functionally, given an information retrieval specification, the IHIA provides the user with the most ‘relevant’ and ‘focused’ information via (a) autonomous HEM-wide navigation; (b) approximate matching of user’s information specification with the HEM contents; (c) content correlation involving the creation of content similarity links between inter- and intra-repositories within the HEM; and (d) information adaptation involving the modification of HEM-specific information to optimally meet the user’s information request. Figure 1 illustrates the functionality of the IHIA. We hope that the use of the IHIA will empower healthcare stakeholders to actively communicate with an ‘information/knowledge-rich’ HEM, and will be able to retrieve with ease ‘useful’ task-specific information via the presentation of cognitively intuitive queries.

2. Agent-Based Intelligent Healthcare Information Assistant: An Overview

In our work, we explore the possibility of leveraging intelligent agents in a healthcare context. Intelligent agents can be viewed as autonomous software (or hardware) constructs that are proactively involved in achieving a predetermined task and at the same time reacting or responding to its environment. Intelligent agents also possess a social ability where they can communicate with other agents using an agent-communication language in the process of carrying out their tasks [6][7].

The IHIA is a framework consisting of: (a) a HEM—a healthcare information web—which provides access paths to diverse information sources; and (b) agent-mediated intelligent access to information sources by approximate matching of resources, content navigation, and content correlation. The IHIA’s focused information search and navigation is grounded in five fundamental principles: (i) it employs specific functionally-autonomous information retrieval agents for each constituent repository within the HEM; (ii) it employs a common ontology modeling the information objects within the HEM; (iii) it collects information via leveraging a medical ontology that assists information matching and
adaptation; (iv) it populates the HEM from only those sources that need to be accessed for relevant content; and (v) it ensures inter-agent communication for agent collaboration to traverse the HEM for ‘holistic’ information retrieval. These principles allow users (e.g., medical practitioners) to access information that is relevant to their current specific needs.

Interaction with a HEM is facilitated by the IHIA, whereby the user’s information needs are specified as an Information Specification (IS)—akin to a query. The inherent medical ontology allows for the expansion of the IS. For example, if a practitioner needs information pertaining to treatment of chronic headaches in the frontal region, the query may comprise the following features or ontological terms: condition: [headache, head pain, ache, pains in head]; duration: [chronic, long time, several months]; location: [frontal, forehead, front of head]; and task: [diagnostic support, diagnosis]. Based on such an IS, the IHIA will activate the intelligent agents to retrieve specific information from the constituent repositories—i.e. the database, case-base, scenario-base and the document-base. Information retrieved from the different sources will provide different perspective to the user, for instance the case-base may provide experiential diagnostic-support, the scenario-base may reflect on the tacit knowledge of domain experts and the document base may provide texts and notes on this topic. The resulting information package is therefore expected to be ‘holistic’, and more attractively it has been retrieved by a simple generic query to the HEM.

The operational workflow of IHIA has been characterized by an agent-based framework comprising five independent agents:

1. Mobile Web-Interface Agent (MWIA): This agent establishes a web-based interface at the client side via the internet/intranet [8][9] and provides the functionality to receive information retrieval specification (i.e. queries) from healthcare practitioners.
2. Query Optimizing Agent (QOA): This agent accepts information retrieval queries from the MWIA, and in turn recomposes the queries in line with the medical ontology and the inherent information access protocols of the various HEM’s repositories.
3. Information Retrieval Agent (IRA): This is the central intelligent agent and is responsible for the autonomous navigation, approximate matching, and content correlation features of the IHIA. Based on the optimized query from the QOA, this agent retrieves the relevant information from the HEM.
4. Information Adaptation Agent (IAA): In case the retrieved information (by the IRA) is not in line with the user’s specification then the IAA can be invoked to operate on the available information and the content correlation links to adapt the retrieved information in order to yield an optimum response.
5. Presentation Agent (PA): This agent prepares and formats the search results to be presented to the user via the MWIA. The results are presented in an intuitive manner so as to allow the healthcare practitioner to make informed decisions.

3. Agent-Based Healthcare Knowledge Retrieval and Adaptation

Here, we highlight two key agents of the IHIA and discuss their tasks in more detail.

3.1 Information Retrieval Agent

At the heart of the IRA is the retrieval manager. In view that the HEM consists of four different storage formats (i.e. databases, case-bases, scenario-bases and document-bases), the retrieval manager manages four broker agents. The retrieval manager obtains the optimized queries from the QOA and passes the specialized queries to the respective broker
agents. These broker agents are then dispatched and will eventually report to the retrieval manager with the results. Figure 2 illustrates the retrieval agent and its components.

The optimized query cache (OQC), which is part of the retrieval manager, keeps a record of optimized queries with pointers to specific data, cases, scenarios and documents that match the queries. When the retrieval manager receives a query, the OQC is verified to see if the same query was made in the past. Therefore, with frequent usage of the IHIA, the OQC will allow the retrieval manager to obtain results more efficiently by pinpointing relevant results without having to search through the entire HEM.

In the event that a query is not found in the OQC, the brokers will then be facilitated by the inverted knowledge indexes (IKI) [10] for the respective databases, case-bases, scenario-bases and document-bases. These IKIs include vectors that contain keywords defining the properties, situations or content of a particular data, case, scenario or document. Each vector also includes a pointer to the respective data, case, scenario or document. The IKI for an exemplar clinical case-base is shown in Figure 3.

3.2 Information Adaptation Agent

In the context of our IHIA, the adaptation agent is more relevant to the retrieval of clinical cases and healthcare scenarios. The adaptation agent of the IHIA employs a case-based reasoning (CBR) technique called compositional adaptation [11][12]. In this technique, the assumption is that the query is similar to multiple pre-existing cases or scenarios and, hence, these cases and scenarios can be combined and adapted to produce a satisfactory result to the query.

4. Intelligent Healthcare Information Assistant Info-Structure

In putting everything together, we present a five-layer IHIA info-structure (see Figure 1 above). The five layers are highly specialized and yet interdependent to achieve the goal of providing intelligent healthcare assistance on demand. The info-structure provides a plug-and-play environment that will allow, in future, other components and agents to be added to further enhance the efficacy of the IHIA.

The medical ontology, that is present at the knowledge description layer, serves as a defined taxonomy of healthcare knowledge and a standard healthcare vocabulary to achieve knowledge standardization [13]. This standardization facilitates the broker agents in their search through the HEM that could potentially contain data, cases, scenarios and documents with different terms for the same concept.

At the object layer, we have medical databases that contain data obtained from various studies, surveys or research. The clinical case-bases contain ‘snapshots’ of actual past clinical cases encountered by healthcare practitioners and experts. Healthcare scenario-
bases, in contrast to case-bases, contain ‘hypothetical’ (but mimicking real) problem situations encountered by healthcare experts together with their intuitive problem solving methodology or tacit healthcare knowledge [5]. Document-bases serve to provide textbook-type information and reference to the user.

5. Concluding Remarks

In our work, we have identified the efficacy of intelligent agents in the IHIA info-structure to address pressing issues concerning healthcare information retrieval. At first glance, one may be tempted to dismiss the IHIA as merely another ‘ordinary’ healthcare information system. However, we argue that the IHIA adds value and is unique because the agents are designed to capitalize on not just references to empirical data, past clinical cases and static textbook-type documents in their retrieval efforts, but also on experiential and intuitive tacit healthcare knowledge that is stored in the healthcare scenario-bases.

We also argue that the use of agent technology is of relevance here in view that, in real life, we expect assistants to be sufficiently competent and independent in delivering the required results. The work on the IHIA is ongoing and the development of intelligent agents in the industry is progressing rapidly. Therefore, we believe that the utilization of agent technology in healthcare knowledge management will prove to be a highly viable solution in providing quality and timely assistance to healthcare practitioners in their service to the masses.

References