Leveraging Ontologies for Improved Fusion of Nanobiotechnology Data: Implementing Medical Management Technology to Drive Innovation

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ABSTRACT

Nanobiotechnology is a growing field within the medical research domain. It involves the use of micro-level sensor systems to effectively target and treat various medical conditions and disease states. These kinds of sensor systems, like others that exist at more macro-levels, produce large amounts of useful medical data, which needs to be extracted, modeled and utilized by subject matter experts (SMEs). Ontologies have proven to be one technology that can provide a means to make sensor data more useful to SMEs. This paper argues that utilizing ontologies in nanobiotechnology areas could produce similar successes and aid in producing new insights into the data gathered by these types of sensor systems.

Keywords: Nanobiotechnology, Ontology, Semantics, Knowledge Management

1 INTRODUCTION

A major problem across biomedical and pharmaceutical research has to do with the capture, modeling and dissemination of large amounts of biomedical data associated with various research areas. Nanobiotechnology represents one such research area where nano-devices are being increasingly used in medical applications [1-3].

2 NANOBIOTECHNOLOGY AS INTEGRATED SENSOR SYSTEMS

Nanobiotechnology in certain applications involves the utilization of small sensor systems which can target specific areas of the body (e.g., individual cells or genetic material) and provide a means to interact with those targeted areas (e.g., delivery of therapies to these specific areas). Sensor systems, in general, must be integrated in terms of their function, as well as in terms of the data that they produce while carrying out those functions. Sensor integration is often treated with algorithmic approaches represented within the field of data fusion [4,5]. Though, while data fusion is a well established field of engineering, challenges can exist for integrating complex kinds of data, such as that produced in the biomedical domain [6]. It can prove difficult to write algorithms around the various entities and relationships that exist in these kinds of complicated fields, since one must utilize certain classifications and logical relations that extend beyond the mathematical approaches of typical data fusion approaches.

3 APPLYING ONTOLOGY TO NANOBIOTECHNOLOGY SENSORS

One technology that has been successfully implemented to capture and manage various kinds of sensor data involves ontologies, whereby large, complex taxonomies can be logically arranged to produce sophisticated data models, which in turn, can be exploited by data fusion algorithms [7-9]. In turn, these models can be exploited by automated reasoners, ultimately providing insights into new relationships and classifications of data elements useful for understanding the outputs of various sensors. This provides a powerful mechanism for providing knowledge management capabilities using ontologies.

Ontology-based knowledge management provides a means for extending micro-level research to other areas of medical discovery (such as clinical trials and other areas of basic medical research). Ontology models created and used at the molecular level of analysis can be linked to clinical areas of medical research providing a further capability to leverage the initial classifications and meta-data generated from nanobiotechnology sensors. Ultimately, information gained at the sensor level can be more easily and rapidly applied to disease treatments and therapies, which leverage the capabilities of those disease models, pharmaceutical products, clinical trials result sets, and medical outcomes data (e.g., lab results, blood chemistries, etc.).

Ontologies allow for their intended semantics to be made explicit, through their formal structure. In ontologies, objects and their relations can be explicitly defined and labeled for easy look-up by individuals who may be designing, augmenting or utilizing the system. Various ontology tools provide forms, relationship panes, graphs, or access to source code, thereby allowing for various independent groups to easily understand how a term is being used within a single ontology using resources they are familiar. Further semantic information can be captured in the ontology through the use of integral metadata: comments, definitions, or descriptions that provide standardized definitions from reliable sources, comments by the system designer, and examples of intended usages. These techniques allow for improved knowledge transfer and management, since SMEs are able to quickly verify the accuracy of another individual's usage of terms within the ontology, plus, novices can quickly gain useful insights into terms or relations that may lie outside their specific area of expertise.

An important consideration in building these systems rests on the ability of ontologies to provide a comprehensive decomposition of complex metaphysical relations such as spatio-temporal relations, logical relations, causal relations, and various sorts of dependence relations, all of which are important for characterizing biomedical sensor data. A comprehensive metaphysical approach is often required for the construction of biomedical ontologies, which can provide consistent and comprehensive models of reality that formally describe the kinds of complex relation-types needed for reasoning about the complex entities found in sensor fusion applications.

3.1 Providing Simplified Semantic Solutions to Make Ontologies Useful to End Users

Even though the use of ontologies is now much more commonplace in numerous areas of sensor research, challenges have arisen pertaining to their ease of use. Many open source ontologies exist for researchers to utilize, yet they are often difficult to integrate and utilize. Many toolsets exist whereby organizations can develop their own proprietary ontology models, yet these can be difficult to conceptually design, maintain and reuse over time. Once researchers settle upon a given ontology approach and/or toolset, a rather steep learning curve exists, in terms of being able to traverse hierarchies, write complex rules, configure reasoning engines, design and execute queries, devise classification schemas (logics), and develop visualized results. These types of tasks require the development of varying theoretical and technical skill sets, the learning of which can detract from the basic day-to-day duties of researchers.

What is needed in today's research environments are easy-to-use ontology-based software systems that can effectively capture domain knowledge, while at the same time, provide a mechanism to project that knowledge across the enterprise. This can be done by combining sophisticated ontology models, on the backend, with powerful visualized analytics tools, on the front end, to provide a comprehensive knowledge management system that can supply intelligence to a variety of users, without forcing them to traverse integrated sets of complicated hierarchies and relational structures. By providing a portal system, as a rich internet application, researchers are provided the capability to perform straightforward analysis of various sorts of biomedical data (blood chemistry data, tissue data, BMI, demographic data, etc), in order to better understand value-based medical outcomes. In such an environment, biomedical information can be presented in a variety of rich visual formats, specific to certain user preferences. This allows domain experts and non-experts alike the ability to more easily traverse large sets of data to find pertinent related information..

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