Adaptive Information Analysis in Higher Education Institutes

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Abstract

Information integration plays an important role in academic environments since it provides a comprehensive view of education data and enables mangers to analyze and evaluate the effectiveness of education processes. However, the problem in the traditional information integration is the lack of personalization due to weak information resource or unavailability of analysis functionality. In this research the layered service-oriented framework was proposed which augmented recommendation approaches with components of semantic based integration to provide adaptive, flexible, and context based information integration and analysis for decision makers in Higher Education Institutes. This framework encompassed the integration of structured information from internal data sources as well as unstructured data from the Web. The main objective of this paper was to adapt the content as well as appropriate services for personalized information analysis. In addition, the framework could enable administrators to analyze instances of education information and receive recommendation of new information sources as well as web services based on the current education status. Service orientation paradigm provides adaptive, flexible, and scalable means of communication for service interoperability and interaction among the framework components. Semantic web technologies help to overcome the heterogeneity among information sources and facilitate on-demand web service discovery and invocation for efficient information analysis.

Keywords: *Personalization, Information Integration, Semantic Web, Service-Oriented Architecture, Higher Education Institute, Adaptive Systems*

1. Introduction

With the development of new information technologies such as Internet, the need for information integration from a number of independent and heterogeneous sources is growing. Although organizations such as Higher Education Institutes (HEI) began to deploy large and complex information systems to support their operational affairs, still the need for comprehensive information analysis which provides the global view of education process is required. In fact, HEI usually need to combine various types of educational data such as student records, schedules, scholarship, and alumni information altogether, preferably in a flexible, scalable and personalized manner, to make a global insight into current state of the education process.

However, in spite of many researches on information integration in the recent years, the need for flexible, scalable, and personalized information integration encourages scholars [1]. Personalization is the process of tailoring information items or services to individual user's tasks or preferences. In this paper, we propose a framework which involves a combination of suitable components of semantic based technologies which provides interactive and flexible information integration and analysis for decision making in higher education institutes such as universities. This framework aims to integrate information sources from internal education database and combines them with relevant information from the Web. In addition, the system enables users to analyze and evaluate instances of information with various analytical tools in a personalized fashion and to incorporate new sources of information and analysis services based on the context.

In the following sections, the higher education institutes and our motivation were described in Section 2. The related works also were analysed in Section 3. Personalization and technology supports in terms of information integration were described in Section 4. A semantic based framework for personalized information analysis was presented in Section 5. The approach in this research was compared with the related works in Section 6. Finally, the conclusion and the results were summarized in Section 7.

2. Motivations

Generally HEI are academic organizations which combine different information systems of under various technological platforms. HEIs need to have a unified access to those information systems in order to monitor and analysis desired information of the education processes. This situation requires the use of distributed information analysis solutions. Information integration and analysis is extremely engaged by diverse communities including academic and educational institutes due to its potential ability to add values to the information [2]. It is therefore crucial for HEIs to analyze and explore hidden relationships between different educational objects such as student progress, courses timetables, education standards, and possibly relevant information from the Web to ensure the effectiveness of the education processes. For instance, information integration and analysis allows the academic administrations to take action for course allocation based on the students' requirements and compare student progresses with standard education metrics extracted from the Web [3].

Bringing together information from different sources that are in different platforms and technologies burden many problems and challenges [4]. Although there are many tools and technologies focus on information integration and analysis, still new problems exist. Laura et al, [5] have addressed several challenges of enterprise information integration (EII) as follows: First, in dynamic environments such as educational environment, a challenge is to provide dynamic data integration when new source of data is required for casual analysis. For example, a particular analysis on paper grows might require additional statistical data from other institutes to enrich the current analysis. Second, one emerging research challenge is incorporating several analytic tools together to provide a personalized information analysis regarding the type of information is being processes [6]. Thus, the challenges include how to supply analytics tools as easy as possible in a flexible communication framework and how to integrate the results of queries on local information with relevant information from the web to gain comprehensive view of education [5].

3. Related Works

The study in [7] presents a semantic desktop which leverages the potentials of semantic web and addresses the challenges of personal information integration. Personalized information integration is accomplished over a wide variety of heterogeneous data on a computer such as emails, hypertext files, etc. For each source of data, an ontology has been used as a common semantic (meaning) of the data items. The ontology contains a conceptual description of data user interested in. It consists of concepts, their attributes, and their relationships. User queries retrieve the relevant data items that are related to a task or application. The system also enables the user to brows and navigates in a hierarchy of folders by means of their conceptual information to find task-relevant personal information. The layered structure of the system encompasses different components including: 1) personal information sources, 2) file description which annotates each data file using metadata consisting a set of properties of the file, 3) domain ontology which includes a set of prebuilt ontologies for different applications like conferences, peoples, and e-mails, 4) application ontology which is a shared ontology and defines as views over the domain of problem.

Similarly, an ontology-based information integration and recommendation system for scholars is represented in [8]. It extracts and integrates important information from domain-specific documents by employing information integration and recommendation approaches. The main technologies employed in the framework are: ontology-based webpage crawler, webpage classifier, information extractor, information recommender, and user interface. The domain of the integration is “scholar information” including all subfield of artificial intelligence. This system uses prebuilt ontology for assisting system’s knowledge analysis tasks. The webpage crawler searches and collects domain related documents, and classifies the web pages by the webpage classifier. The system then invokes the information extractor to gather three main areas of information from the web pages: course information, website recommendation, and academic activities. The information extractor combines data both from the webpage crawler and the webpage classifier and extracts significant information. The information recommender filters out the data items of the classified pages corresponding to the scholar information, and integrates and ranks this information to the users.

Moreover, SSOA-E [9] is a semantic service-oriented approach for education information integration. It employs Service Oriented Architecture (SOA) as the integration platform, data integration, and application integration for the domain, i.e. education information systems. It enriches the traditional SOA architecture by the use of OWL (Ontology Web Language) as semantic description of education information and OWL-S (Ontology Web Language for Services) as education services’ semantic description. This architecture provides effective education resources sharing which provides semantic discovery and dynamic composition of education services. SSOA-E includes four layers: education resource layer, semantic service layer, education application layer, and user interface layer. Education resource layer is an infrastructure in which the whole education resources including computing resource, storage resource, software resource, and knowledge resource, are connected together that realizes heterogeneous systems interconnection. Semantic service layer provides semantic supports for service description, publishing, discovery, matching, and composition.

Education application layer automatically match, compose, and execute appropriate services such as digital library, instruction and training, research, educational administration, student information management. User interface layer builds user interfaces for end-user such as web portal.

Khapre et al, [10] also propose a customized user profile and service selection algorithm in business settings for different steps of personalization as user interacts with the system. The system compares the content of user profile with the services user requests and discards not matching services dynamically and provides useful recommendations services respect to user preferences. The core components of the proposed approach are: 1) the user's plan/goal, e.g., managing a trip, 2) the discovery of existing services which matches the available services corresponding to the plan, 3) the service selection which decides what services to be consumed to address the required task, and 4) the service composition which deals with the decomposition of a complex task into sub-goals which can be performed by simple or atomic services. In the proposed framework, all of these steps are personalized based on the user profile, presented by an ontology. In this case, the user profile, service discovery, and service composition are totally engaged by means of semantic web technologies.

4. Literature Review

Personalization technologies have been extensively employed in a wide variety of domains such as electronic education, e-business, and electronic news to tailor the system output with the individual user's preferences [11]. In fact, personalized approaches aim to detect user tastes and conforms the output of enquiry to the actual needs of the user by filtering unrelated results and recommending those objects (information, products, services, etc) that deemed user to be interested in. Recommender system builds the model of interactions the users have with the system, known as "user profile". In essence, the user profile is a structured representation of characteristics of user's requirement during the system interactions. It defines explicit and implicit information about the user's needs and has been used to predict and rank the contents or services according to preferences of the individual users. User profile maintains user's preferences or items the user already rated. Personalization process then recommends those unseen objects that are most similar with the items in the user profile. User profiles are usually made up based on the user score of items rated during the user interaction with the system.

Fortunately, Semantic Web Technologies (SWT) and interoperability paradigms such as Service Oriented Architecture truly support the aforementioned requirements for personalized information integration in a distributed environment such as Internet [12]. Today, Semantic Web and Web services (WS) are the basic building blocks of information sharing and information integration [13]. A Web service is a platform-independent, loosely coupled program that can be executed over the network such as Internet and is accessible through an interface which specifies the physical address as well as the messages that a client can consume it. The actual consumption of the Web service is realized by exchanging of XML data over the network via SOAP protocol which is a service access protocol for which invokes a Web Service. Transport protocols over the internet such as HTTP, FTP, and other transport protocols may be used with SOAP with different purposes. Alonso, et al. [14] argued that SOA allows developers to overcome many challenges in distributed computing including enterprise information integration.

Web services technologies and SOA interconnectivity paradigm has been adapted by several standardization and technologies including: 1) Semantic-based Web Service Description Language (WSDL-S) which specifies adequate information on how clients can access to the web services, 2) SOAP, a messaging technology for exchanging XML data over the Internet, and 3) UDDI (Universal Description, Discovery and Integration Protocol) which is a registry technology for registering and publishing Web services over the Internet.

Semantic Web Service technologies (SWS) provide appropriate techniques for automatic detection and consumption of Web services over the network for solving a particular client request within the SOA architecture. To achieve this goal, ontology has been employed as the underlying data model in SWS approaches to specify formal knowledge for the Semantic Web Services. In fact, ontologies provide a pure data model for the domain of discourse (domain problem) by enriching information with description of data items and bridge the gap between real world and the information source [15]. In essence, they support integration of heterogeneous data sources by defining mappings between ontologies and the date model of information sources.

Moreover, Semantic Web provides the following supports to our integration problem: 1) Formal ontology languages for describing information sources [16], 2) Ontology management technologies for ontology engineering task such as development and maintenance, 3) Techniques for supporting ontology-based data integration [17], and 4) Processing capability of Semantic Web technologies such as Web services [18].

5. The Framework

In the proposed framework, components interacted by means of service invocation and standard message passing [19]. Each source data was wrapped by an appropriate service and services are executed in an on-demand fashion. The architecture of the framework was based on SOA paradigm encompasses five different layers: information source, presentation, semantic, Web service, and communication layers. Layering principle was followed because it appropriately supports strong separation of concerns and loose coupling that, in turn, provides flexibility and scalability for the architecture [20]. It benefits from Web Service technologies which provide easy interoperability among framework components by relying on semantic standards.

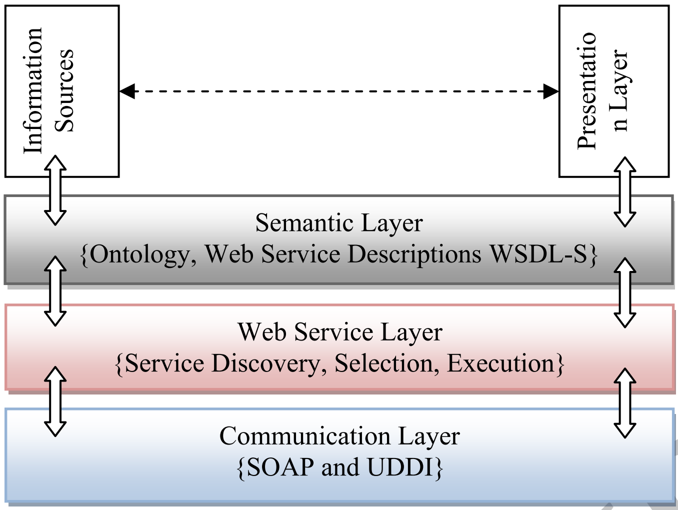

Figure 1. Conceptual structure of the semantic based framework

As illustrated in Figure 1, both Web services and semantic layers played the key role in the architecture because they provided an interface between information sources and presentation layer. In fact, presentation layer (user interface) access the information sources through three inter-related layers including semantic, web services, and communication layers. The dash line makes a logical association between information and presentation layers. As mentioned in previous sections, it was aimed to address a flexible and scalable personalized framework for information integration analysis. In this view, layered structure provides sufficient flexibility and scalability as well as scalability for the proposed framework [20].

Moreover, layered structure consolidates the dynamic interoperability between components because components can be easily replaced and upgraded without affecting other layers. Furthermore, this architecture assists decision makers to interact with the system by incorporating their own analysis tools, including sophisticated tools via presentation layer.

5.1 Information Sources

In most HEIs, many pertinent information sources are existed from which to make decisions including internal sources such as academic records, and the Web information such as researcher home pages. The flexible and efficient information integration system must enable knowledge workers to dynamically bring in and out information sources from these sources in order to make effective decision. The dynamic nature of the Web implies that some information sources are relatively temporary and therefore cannot be involved permanently into the system. Thus, they should be replaced with the new ones on-occasion by support of semantic web service approaches which wraps information source and helps resolving heterogeneities. Besides, new information may be required based on the individual student records to fulfill specific analysis.

A global ontology describes the general keywords of HEI domain including structured information such as courses, events name, graduation steps, progress report and so on. Each information source is described by a local ontology, fine grained concepts and their semantic relationships. Mapping between global ontology and local ontology is employed to resolve concept of heterogeneity among different sources [21]. An ontology engineering mechanism by means of a service can be used to keep track of changes in local ontologies due to source replacement and concept renewal. As an illustration, if a student is going to graduate, relevant job opportunity from the Web sources such as portals will be recommended to the user. Since this form of information is unstructured, information retrieval techniques can be used to extract relevant information. The global ontology helps to overcome structure inconsistency that potentially exists among local structured data and retrieved data from the Web. Finally, new terms of the analysis affects the “context ontology” and the recommendation source recommend relevant information sources based on the new terms such as “scholarship”, “finance”, and “alumni” information.

5.2 Semantic Layer

The Semantic layer plays three important roles in the proposed framework: 1) enriches information sources to overcome information heterogeneities, 2) facilitates discovery, composition, and execution of services, and 3) keeps updated the “context ontology” when users issue a query.

Diversity through information sources imposes many heterogeneities problems such as the lack of common semantic among data items. Semantic Web technologies such as ontology provide a global conceptualization (common terms) of information sources. Since information sources are not mandatory and replaced during the analysis, ontology engineering techniques that enable users to make local source ontology at run-time is employed.

To facilitate this process, employ hybrid approach is employed [21] for domain conceptualization. In the hybrid approach, the semantics of each source is described by a particular ontology. Furthermore, in order to make the sources ontologies compatible and comparable to each other, they can be constructed based on a shared vocabulary. The shared ontology encompasses basic terms of the domain. Since each term of the local ontology is based on the basic terms, the terms of involving ontologies can be easily mapped to each other [22]. In fact, the domain ontology is a partial refinement of the terms of global ontology. Since domain ontologies only use terms of the global ontology, they remain compatible and easily comparable [23].

The advantage of using hybrid approach in the framework is that it allows new information sources easily replaced without the need of changing the mappings between data source and the concepts of shared ontology. However, the drawback of hybrid approach is that existing ontology cannot be easily reused in other domains and also required developing from scratch, because all ontology terms refer to the shared ontology’s terms. Thus, some parts of ontology mapping, i.e. mapping between concepts of the information sources and the global ontology, may require user modification.

In addition to this role, the Semantic layer facilitates automated Web service discovery, composition, and execution of Semantic Web services [17]. All functionalities in this layer are ontology development and maintenance. Information query and analysis are supported by the Semantic layer. This layer provides required flexibility to deal with dynamic aspects of the framework in which information source can be easily added or replaced, for example, regarding the students’ status. It provides facilities for better support of detection and consumption of Web services in the framework. Therefore, semantic web service uses ontologies as the underlying data model to specify the knowledge model of the Web services. All services in the framework can be described by WSDL-S language which augments semantic tags to WSDL data types as well as the messaging type and operations. WSDL-S also provides efficient discovery and composition of services, since it augments semantic features and functionality with service specification, allowing for better semantic search, efficient service mediation and automatic service composition [13].

The semantic layer also maintains the context ontology entity to provide final version of context vocabulary that user might need to know more about them. The context ontology supports personalized query and service invocation by enriching query terms and service discovery.

5.3 Web Service Layer

In the proposed framework, the foundation of communication model is SOA and the underlying processing components are Semantic Web Services. Therefore, it supports better service interoperability and facilitates easier service integration and better automation of service discovery, composition, and execution [17].

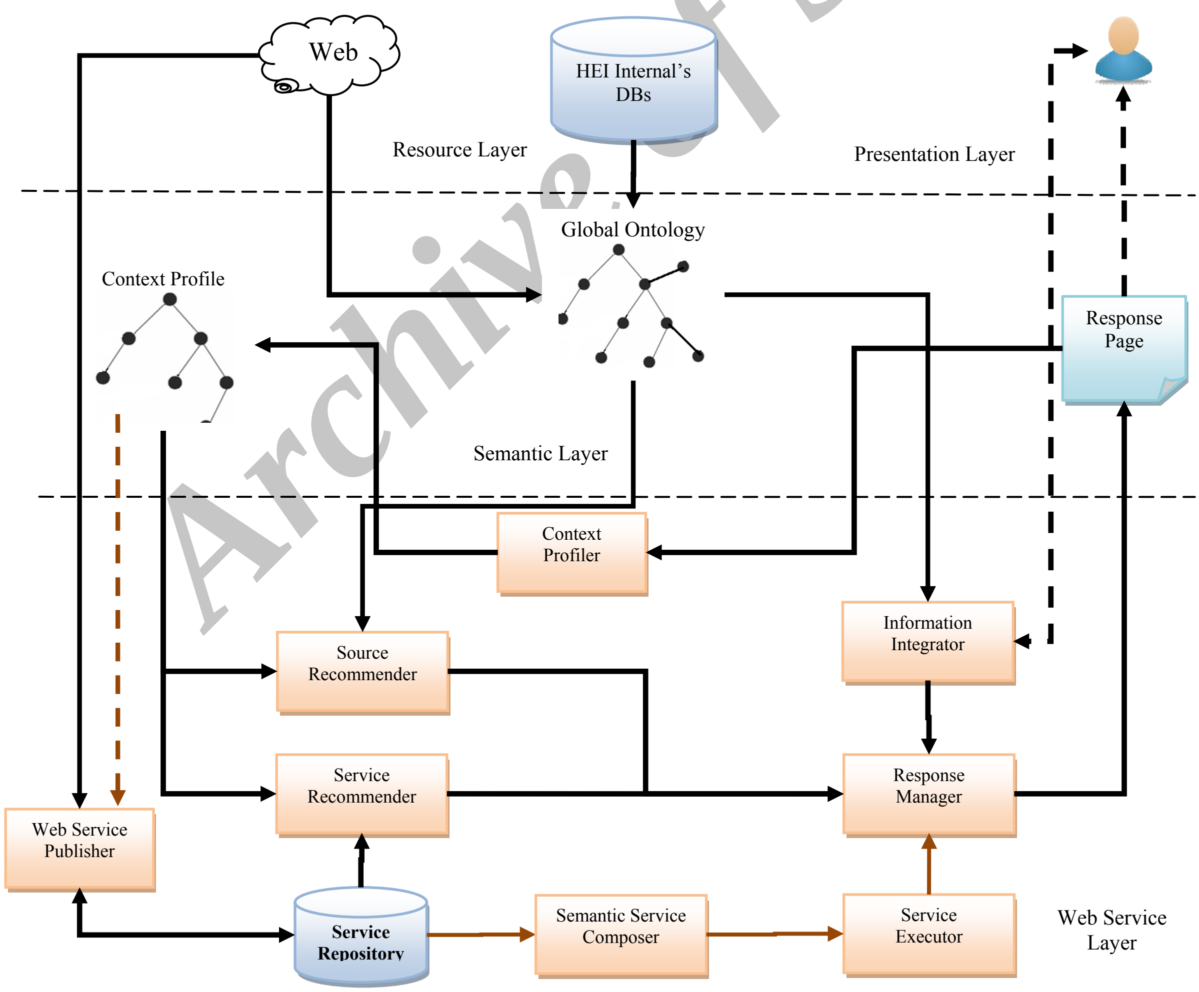

Figure 2. Basic components of Web Service Layer in relation with other layers in the framework

As illustrated in Figure 2, this layer in relation with its adjacent layers provides fundamental services for supporting information integration tasks, ontology management, and basic run-time services for service registration, discovery, composition and execution. It also encompasses source and service recommenders [24], context profiler, and information integrator. This layer allows diverse kind of system component including legacy tools for information analysis, wrapped to form a semantic web service and, therefore, can be incorporated in the architecture at run time. These services exploit semantic description provided by the semantic layer in order to provide transparent and dynamic service discovery and invocation in the framework.

An important component of semi-automatic service composition and execution is the discovery of the required services [9]. The run-time service management in the framework deals with the service discovery, selection, and execution. The functionality and the semantic specifications of all Web services in the service repositories can be formally described by WSDL-S language which supports semantic search techniques for more precise Web service discovery. Semantic matchmaking of functional descriptions helps the discovery of the registered Web services and detection of suitable candidates for an analysis or a particular presentation service. The usability of the discovered services can be determined by Service Composer component (selection and ranking of service) either to selects one of the candidates or recommends a priority list for user's selection. In this case, user is allowed to select an appropriate service manually to accomplish his task. If a single service satisfies the user request, then the service executor is automatically called the respected Web service in order to accomplish the user's request. Otherwise, the service Composer combines a series of suitable Web services for solving the user request.

Web Service component aim to crawls the web for relevant published web services on the web corresponding to the context profile and download and register in service repository. Conversely, it replaces the unused or outdated web services based on a usage tag or time stamp. This functionality is useful to prevent maintaining a large number of irrelevant services that may be no longer in used and increase the performance of web service discovery.

Context Profiler (CP) in the framework processes "response page" and employs information retrieval approaches such as statistical analysis approaches to determine important vocabulary of information that user is analyzing and updates context ontology. In fact, CP identifies those important terms that best describe the student status and helps the two recommenders in the framework, i.e. source and service recommender, to recommend most relevant source of information and service (for analysis) to the user.

5.4 Communication Layer

Communication layer provides a medium that allows Web services exchanging messages by means of SOAP protocol. The Web service layer was separated from the communication layer in order to emphasis on flexibility in the framework. The basic elements of Web service technology such as SOAP and UDDI enables the provision of Web services usage (service discovery and invocation) over the Internet [23]. The components of the proposed framework which are a collection of Web services by means of these technologies can be efficiently and easily run over the distributed platform such as Internet. It was relied on Internet as stable communication platform because it adds enhancement to traditional communication methods for information integration. Moreover, depending on the integration situations, the Web services could be originated from one source or multiple sources interconnected over the communication network. Thus, the Internet plays two important roles in the proposed framework; it provides Web services for users as well as interconnects Web service components for exchanging message and communication.

5.5 Presentation Layer

This layer deals with data visualization which engages a wide variety of tools for presentation the information contained in the information sources. Efficient visualizations can make complex relationships among piece of information easily understandable [25]. This layer helps all aspect of education information including trend analysis, performance of teaching and supervision, and other academic information easily analyzed in a service-based manner. All of these analyses can be accomplished by means of third party tools which are wrapped as a Web Service. This layer is simply a Web browser which enables users to pose queries and navigate through the information and access the Web service repository through the links offered by the recommenders in the web service layer.

6. Evaluation

In order to evaluate the framework compared to the similar works, technical and structural metrics were considered. Measurement should address the technical aspects of the framework such as flexibility and scalability as well as inherent features of personalization. Service orientation approach fosters sufficient flexibility to the framework because processing capabilities such as ontology management could easily be implemented by means of semantic web services. Furthermore, it enables the framework to include new source of data as well as new Web services over the time, providing system scalability. Similarly, web services can effectively be discovered, composed, and invoked by means of Semantic web description facilities Semantic Layer. Personalized information integration is accomplished by means of ontology where domain ontologies describe the individual source data. Global ontology, on the other hand, provides a common description of the concepts in the domain of discourse. At the same time, personalized information analysis is supported by semi-automatic service discovery and composition where user can exploits a ranked list of appropriate services that fir the user goal.

In Table 1, a comparison of the proposed framework with the proposals of the rated works was presented. As shown, flexibility and scalability are supported by those approaches that employ SOA and the semantic subservices. On the other hand, those approaches which do not exploit from service orientation suffer from interoperability. Meanwhile, personalization is a step toward dynamic composition of analysis services that would truly be implemented by means of contextual profile.

Table 1. A comparison of related work with the proposed framework

Work	Flexibility	Scalability	Service Interoperability	Personalization	Scope
I.F. Cruz, H. Xiao, (2008)	NO	NO	Static	YES	Personal data on desktop computer
L. Srinivasan, J. Treadwell, (2005)	NO	YES	Static	YES	Scholar information, including all subfields of artificial intelligence from the Web
S. Y. Yang, (2010)	YES	NO	Dynamic	NO	Education information systems (application integration)
S. Tang, Z. Zhang, B.C. Pang, C.C.T. Lim, and T. Ang., (2009)	YES	NO	Dynamic	YES (only data)	A business domain
Our framework	YES	YES	Dynamic	YES	Education domain including internal sources and the Web

7. Conclusion

This paper proposed a semantic service-based framework which supports personalized information integration and analysis for higher education institutes. The principles of the semantic Web technologies such as ontology, Web Service, and service oriented architecture to address the dynamic combination of information as well as personalized web services for flexible analysis. Technical aspects such as dynamic tailoring of information sources and the contextual adaptation of web service composition were examined. To overcome the traditional challenges of information integration, the use of a flexible and open interoperation environment such as Internet was employed. Working example showed that the framework can assist the managers to analyze a wide variety of relevant information and perform contextual analysis based on the current academic status. The proposed framework was also different from traditional recommender systems because it recommended objects (information items and services) based on the situation of current analysis but not based on the user interests. Compared to the existing approaches, the main achievement of the framework was to facilitate the particular user's needs by offering relevant information items and service functionality simultaneously in a flexible and scalable manner.

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