Web Service Architecture for Computer-Adaptive Testing on e-Learning

M. Phankokkruad, K. Woraratpanya

Abstract**—**This paper proposes a Web service and service-oriented architecture (SOA) for a computer-adaptive testing (CAT) process on e-learning systems. The proposed architecture is developed to solve an interoperability problem of the CAT process by using Web service. The proposed SOA and Web service define all services needed for the interactions between systems in order to deliver items and essential data from Web service to the CAT Web-based application. These services are implemented in a XML-based architecture, platform independence and interoperability between the Web service and CAT Web-based applications.

Keywords**—**Web service, service-oriented architecture, computer-adaptive testing, e-learning, interoperability

I. Introduction

THE student assessment is always a very important phase in learning processes. The assessment helps teachers evaluate the student's ability level of knowledge. In e-learning systems, the multiple-choice test is a widely used method for an assessment, especially an adaptive test. The adaptive test is an effective testing method that items are adapted to approach to the ability of an individual examinee. This makes learning assessment improve the higher level precision to identify items to the examinees. That is, the examinees do not waste their time attempt on items that are too hard or too easy. In the part decade, the adaptive testing method has been applied to the assessment of computer-based learning and e-learning. It is recognized as computer-adaptive testing (CAT). The successful implementation of the CAT system was proposed in [1]. This system is comprised of an item bank and a managing algorithm. The item bank is based on item response theory (IRT) [2]. That is, each item contains three principal parameters; discrimination, difficulty, and guess. These parameters are made use of making decision in the CAT system, so that the suitable item is adapted for each examinee. In order to achieve the efficient decision-making process, the IRT parameters are implemented with a triangle decision tree (TDT). Then a managing algorithm used genetic algorithms (GAs) is applied to TDT so as to generate an optimal tree. By this method, the items are automatically selected from the item bank to correspond to the estimated ability level of students.

Although the CAT system proposed in [1] has been implemented successfully, it has not provided its services for different platforms on e-learning. This is because the system did not offer the interoperability for item interchange between systems. The interoperability is an interconnection of heterogeneous systems and allows the communication of different applications from different sources to each other. In order to provide the interoperability to the CAT system, a Web service, an efficient technique, is proposed to overcome the interoperability issue on e-learning. Moreover, the Web service is operating system independent; it can work with every Web service engine regardless of their programming language.

An interest case of the interoperability for an e-learning system was proposed in [3]. The main idea of this paper was identifying and creating the essential services, which help the different software, e-learning tools, and systems link together. The method identified the functionality needed to enhance interoperability for Web service-based e-learning and focused on the steps to transform the digital assets into the digital learning resources which lead to create the services. These services increased the efficiency of e-learning systems by allowing the different platforms to interact with each other. However, this method did not propose the architecture or any data structures for services. Thus, the suitability of different applications and platforms did not allow. Many researches [4, 5, 6] have been applied Web services to e-learning systems to deliver appropriate learning resources. These Web services focused on selecting and combining the learning contents. They have been implemented in an adaptive learning environment and some architecture has been proposed for scalability and reusability of the contents. Unfortunately, no works have been proposed the Web service for the CAT systems absolutely. For this reason, this paper addresses the problems of CAT interoperability using Web service. An interchange of data of the CAT system between a Web service and a web application is based on a service-oriented architecture (SOA) [7]. SOA is a methodology in software engineering designed to describe distributed data. Thus, it is the most suitable implementing method for the Web service and web application that communicates with each other via the Internet.

The rest of this paper is organized as follows: Section 2 introduces a brief theoretical background, a proposed architecture, a problem definition, a design of SOA, and a

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Web service used in the interchanging of the CAT items. Section 3 proposes an implementation of a Web service and SOA. Section 4 discusses the results. Finally, conclusions are given in Section 5.

II. Proposed Architecture

In this section, the state of the problem is described. These problems are used to design the Web service and SOA. The brief definition, architecture, and services are also introduced.

A. State of the problem

CAT [8] is a method for administering tests that adapts to the examinee's ability level by a computer. The presentation of each item and the decision to finish the test are dynamically adapted to the examinee’s response. This response is used to evaluating and selecting the next question administered by the latest examinee’s estimated ability. CAT is used to make the precision scores higher for most examinees than traditional tests. Normally, the CAT system delivers the items and learning resources to the web application via the Internet, but the different platform makes a data delivery incompatible. Thus, the limitation of the CAT system is an interoperability of the data delivery between heterogeneous systems. For this reason, a Web service [9] is applied to extend this limitation. The Web service is a software system designed to support interoperable networking interaction and platform independent over the Internet. However, the interchange of data between Web services and between systems needs to define the standard data format for communicating with each other. All resources are regarded as services. In essence, a SOA is a collection of services that can communicate with each other through XML message in several services. The Web Service is the most suitable implementation technology available for the SOA.

B. Design of Web Services

In order to solve the CAT problem, SOA and Web service are designed by using a general software architecture principle composed of encapsulation, modularization, and separation. Based on Treadwell’s steps [10], the designing process starts with breaking the different pieces of testing algorithms and requirements into services, such as item and database. These services encapsulate the capabilities of a software system; they can communicate with each other using the different message exchange patterns.

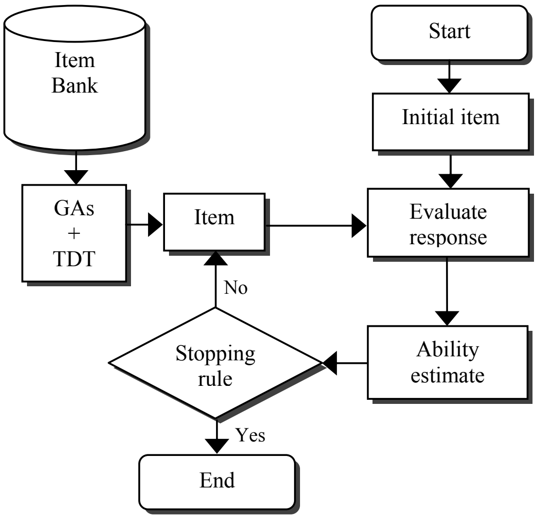


Fig. 1 CAT Flowchart.

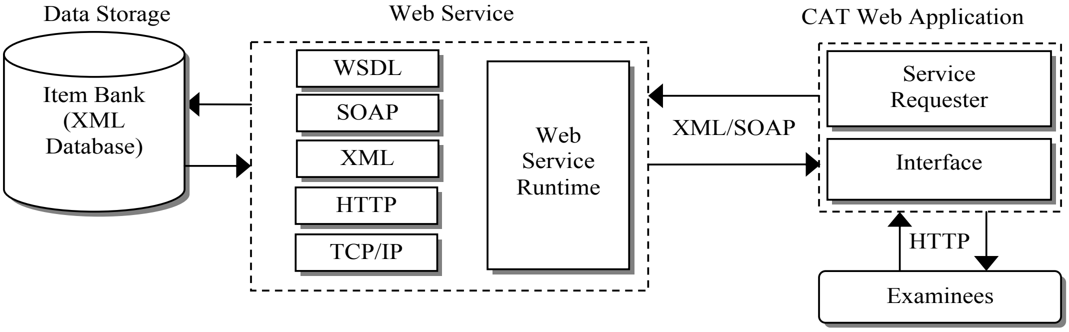


Fig. 2 System Architecture.

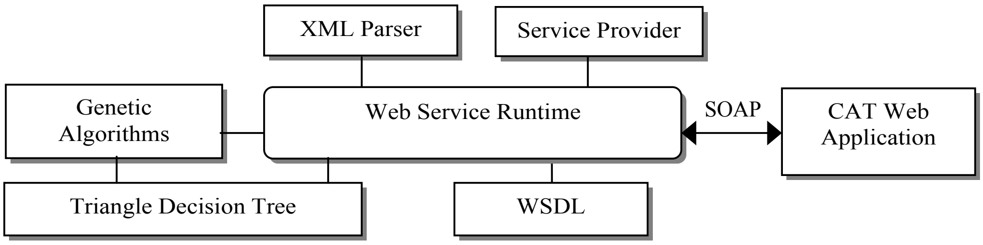


Fig. 3 Web Service Architecture.

Normally, the services provide the data needed in the general CAT web application and some data in the test. The item is the multiple-choice test consisting of four choices, an answer, IRT parameters, and a question. These items are stored in the XML database (XML-DB). TDT is applied to the adaptive testing process as the decision-making technique to classify the appropriate items for the examinees. TDT is decision tree comprised of nodes and branches. In order to generate an optimal decision tree, a GAs is implemented as a classifier.

The flowchart of a CAT system shows in Fig. 1 is an iterative algorithm with the following steps. An item bank is searched for the optimal item based on the examinee's current ability estimate. The chosen item is presented to the examinee by considering the answer is correct or wrong. The ability estimate is updated and based on all prior answers. The process is repeated until a stopping rule is reached.

Fig. 2 shows the overall architecture by applying a SOA concept. The architecture is separated into the three parts; data storage, Web service, and CAT Web application. In data storage, the XML database stores items. An item bank data structure is described in an XML document. The item structure is a subject to a XML schema developed according to the most standards [11]. This database structure is designed by using the basic data structure of the general testing parameters, such as question, multiple choice, answer, and IRT parameters. These testing parameters are assigned with the XML elements as shown in Table I.

TABLE I
DATA STRUCTURE OF THE CAT ITEM

Field	Description	Data type
Index	Item index	Number
QUE	Question	String
QA	Choice A	String
QB	Choice B	String
QC	Choice C	String
QD	Choice D	String
QANS	Answer	String
IA	IRT Discrimination	Single
IB	IRT Difficulty	Single
IC	IRT pseudo-guess	Single

An example of a XML schema is shown in Fig. 4, where IA, IB, and IC denote discrimination, difficulty, and pseudo-guess of the IRT parameters, respectively. The QA, QB, QC, and QD in line 15 to 22 are the multiple-choice, QUE in line 18 is the question, and QANS in line 23 is the answer.

In Web service design, a set of standards for describing, publishing, discovering, and binding application interfaces are consisted of WSDL (Web Services Description Language), SOAP (Simple Object Access Protocol), UDDI (Universal Description, Discovery and Integration). WSDL is a format for describing a Web service interface. It describes services and a way they should be bound to specific network addresses. The descriptions of services and messages are generally expressed in XML (eXtended Markup Language). SOAP provides the envelope for sending messages via the Internet. UDDI defines a set of services supporting the description and discovery of service providers. The design of Web service consists of four main modules—GAs, TDT, SOAP, and WSDL—as shown in Fig. 3. The GAs is the item classification method to generate an optimal decision tree. TDT is a decision-making structure that uses a model of decisions tree. WSDL is an abstract definition of messages and allows the reusable abstract definitions [12]. It also provides a common language to describe the services and a platform to integrate the services [5]. WSDL is a format for describing the services and messages which are generally expressed in XML. In this research, the services and messages are the items and learning resources. Thus, WSDL is used to describe the items and their related data. SOAP provides the envelope for sending the items and related learning data as the messages via the Internet. These messages are encoded and defined a specification in a common XML format.

```
01: <?xml version=”1.0” encoding=”utf-8” ?>
02: <DataTable xmlns=" http://.../CATServer/">
03: <xs:schema id="NewDataSet" xmlns=""
04:  xmlns:xs="http://www.w3.org/2001/XMLSchema"
05:  xmlns:msdata="urn:schemas-microsoft-com:xml-msdata">
06: <xs:element name="NewDataSet" msdata:IsDataSet="true"
07: msdata:MainDataTable="TDT"
08: msdata:UseCurrentLocale="true">
09: <xs:complexType>
10: <xs:choice minOccurs="0" maxOccurs="unbounded">
11: <xs:element name="TDT">
12: <xs:complexType>
13: <xs:sequence>
14: <xs:element name="IA" type="xs:single" minOccurs="0" />
15: <xs:element name="IB" type="xs:single" minOccurs="0" />
16: <xs:element name="IC" type="xs:single" minOccurs="0" />
17: <xs:element name="QUE" type="xs:string" minOccurs="0" />
18: <xs:element name="QA" type="xs:string" minOccurs="0" />
19: <xs:element name="QB" type="xs:string" minOccurs="0" />
20: <xs:element name="QC" type="xs:string" minOccurs="0" />
21: <xs:element name="QD" type="xs:string" minOccurs="0" />
22: <xs:element name="QANS" type="xs:string" minOccurs="0" />
23: </xs:sequence>
24: </xs:complexType>
25: </xs:element>
26: </xs:choice>
27: </xs:complexType>
28: </xs:element>
29: </xs:schema>
```

Fig. 4 XML schema of the item bank data structure.

Finally, the CAT web application provides interfaces for implementing the proposed architecture. The layout of this application is created for communicating with Web service. The CAT web application requires a Web service by passing the parameter values that the examinee has selected, and then it gets back the response items as the service to display them on the screen.

III. Implementation

The system is implemented entirely in ASP.NET Web service and operated on Internet Information Services (IIS) Web server. A CAT web application is created using ASP.NET and HTML. Because an ASP.NET is chosen, it is the most popular programming language and easy to debug. The Microsoft .NET framework library generates WSDL and SOAP message automatically.

A SOAP message is encoded in a common XML format and it is also defined as a specification for a XML-based distributed computing infrastructure. An example of a SOAP request is shown in Fig. 5. The SOAP message is composed of two parts: mandatory and option. The mandatory parts are: SOAP envelope (in line 02) defines a framework for describing a message, SOAP body (in line 06) contains the message for the endpoint; the optional part includes SOAP header. In order to test the service and exchange messages between servers, the SOAP messages and responses are created.

```
01: <?xml version=”1.0” encoding=”utf-8”?>
02: <SOAP:Envelope
03: xmlns:xsi=”http://www.w3.org/2001/XMLSchema-instance”
04: xmlns:xsd=”http://www.w3.org/2001/XMLSchema”
05: xmlns: SOAP=”http://www.w3.org/2003/05/soap-envelope”>
06: < SOAP:Body>
07:<TDT_Table xmlns=”http://.../CATServer/” />
08: </ SOAP:Body>
09: </ SOAP:Envelope>
```

Fig. 5 SOAP specification of the web services.

WSDL uses the following elements as the definition of network services: types, message, abstract, operation, port type, binding, port, and service. An example of WSDL is shown in Fig. 6. Types (in line 08) is a container for data type definitions using some type system; Message (in line 12) is an abstract, typed definition of the data being communicated; Operation (in line 16) is an abstract description of an action supported by the service; PortType (in line 15) is an abstract set of operations supported by one or more endpoints; <Binding> is a concrete protocol and data format specification for a particular port type; Port (in line 25) is a single endpoint defined as a combination of a binding and a network address; and finally a Service (in line 24) is a collection of related endpoints. The CAT web applications are created using ASP.NET and HTML. The items are delivered to the CAT web applications using .NET Web service. The items are stored in XML database.

The proposed architecture is implemented by using the standard of Web services. A Web service and CAT Web application are developed in order to verify the programming algorithms, communication message, and services. Some application specifications, returned messages, and parameter values are examined.

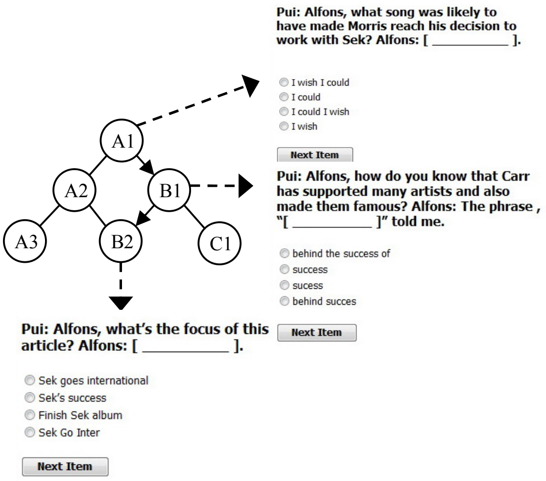
```
01: <?xml version=”1.0” encoding=”utf-8” ?>
02: <wsdl:definitions
03: ....
04: xmlns:tns=" http://.../CATServer/"
05: ….
06: targetNamespace=" http://.../CATServer/"
07: xmlns:wsdl="…">
08: <wsdl:types>
09: <s:schema elementFormDefault="qualified"
10: targetNamespace=" http://.../CATServer/">
11: </wsdl:types>
12: <wsdl:message name="TDT_TableSoapIn">
13: <wsdl:part name="parameters" element="tns:TDT_Table" />
14: </wsdl:message>
15:<wsdl:portType name="Service1Soap">
16:<wsdl:operation name="TDT_Table">
17:<wsdl:input message="tns:TDT_TableSoapIn" />
18:<wsdl:output message="tns:TDT_TableSoapOut" />
19:</wsdl:operation>
20:</wsdl:portType>
21:<wsdl:binding name="Service1Soap" type="tns:Service1Soap">
22: ….
23:</wsdl:binding>
24:<wsdl:service name="Service1">
25: <wsdl:port name="Service1Soap" binding="tns:Service1Soap">
26:<soap:address location="http://.../CATService1.asmx" />
27:</wsdl:port>
28:<wsdl:port name="Service1Soap12"
29: binding="tns:Service1Soap12">
30:<soap12:address location="http://.../CATService1.asmx" />
31:</wsdl:port>
32:</wsdl:service>
33:</wsdl:definitions>
```

Fig. 6 An example content of WSDL.

IV. Results and Discussions

In order to verify the proposed architecture, the CAT web application is developed by ASP.NET. The items for implementation are the English reading comprehension test. A CAT Web application is created for communicating with Web service via HTTP by sending the item request message. When the Web service received the request message, the following process is operated. Firstly, the Web service requests the items from the database, this request could be separated in two methods: single item and item set. Secondary, the response items from database are classified by GAs. These response items are encapsulated in a XML format and sent it back to the CAT web application. Finally, the CAT Web application is used the received items in the CAT process by following the TDT rules until the test is finished. Fig. 7 shows an example of an interface screen result.

From the implementation, the request and response message are verified by the developing of CAT web application. The development and verification processes are followed by an instructional systems design (ISD) model which is currently accepted as an industry standard for instructional design of educational application [13].



Pui: Alfons, what song was likely to have made Morris reach his decision to work with Sek? Alfons: [__________].

○ I wish I could
○ I could
○ I could I wish
○ I wish

Next Item

Pui: Alfons, how do you know that Carr has supported many artists and also made them famous? Alfons: The phrase , "[__________]" told me.

○ behind the success of
○ success
○ sucess
○ behind succes

Next Item

Pui: Alfons, what's the focus of this article? Alfons: [___________].

○ Sek goes international
○ Sek's success
○ Finish Sek album
○ Sek Go Inter

Next Item

Fig. 7 An example of CAT interface screen

In order to verify the correction of data, a six-level TDT of items is the main verification pattern, because it is used in examination and the standard pattern has only six levels. The standard pattern is shown in Fig. 8. When compared the item in CAT Web application interface with the standard pattern, it is found that every item is located at the right position on a TDT diagram as described and demonstrated in [1].

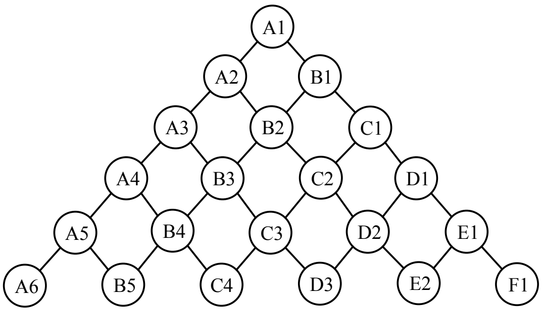


Fig. 8 six-level standard pattern of a TDT diagram.

V. Conclusion

In this paper, the proposed architecture has developed to improve interoperability of the CAT system for platform independent. A Web service and SOA have defined all services needed for the interactions between systems in order to deliver items from Web service to the CAT Web application. The system has implemented in ASP.NET Web service and Web application for interface. The design of SOA and Web service for CAT on e-learning can interoperate the learning resources. This makes the system more flexible.

References

[1] M. Phankokkruad and K. Woraratpanya, "An Automated Decision System for Computer Adaptive Testing Using Genetic Algorithms", The 9th ACIS International Conference on Software Engineering, Artificial *Intelligence, Networking, and Parallel/Distributed Computing (SNPD2008)*, 2008, pp.655-660.

[2] Frank B. Baker, "The Basics of Item Response Theory", *ERIC Clearinghouse on Assessment and Evaluation*, 2nd Ed, 2001.

[3] A. Grewal, S. Rai, R. Phillips and C. C. Fung, "The E-Learning Lifecycle and its Services: The Web Services Approach", *Proceedings of the Second International Conference on eLearning for Knowledge-Based Society*, 2005, pp.4.1-4.8

[4] V. Pankratius, O. Sandel and W. Stucky, "Retrieving Content With Agents In Web Service e-Learning Systems", *Symposium on Professional Practice in AI*, First IFIP Conference on Artificial Intelligence Applications and Innovations (AIAI), 2004, pp. 91-100.

[5] K.K. Thyagharajan and R. Nayak, "Adaptive Content Creation for Personalized e-Learning Using Web Services", *Journal of Applied Sciences Research*, vol.3(9), 2007, pp.828-836.

[6] Z. Xu, Z.g Yin, and A.E. Saddik, "A Web Services Oriented Framework for Dynamic E-Learning Systems", *IEEE CCECE–CCGEI 2003*, Montreal, 2003.

[7] L. Jing, Z. Li, and Y. Fang, "Information Management in E-Learning System", *Advances in Web-Age Information Management*, Springer Berlin / Heidelberg, 2005, pp.275-283.

[8] R. Conejo, E. Guzman, E. Millan, M. Trella, J. L. Perez-De-La-Cruz and A. Rios, "SIETTE: A Web–Based Tool for Adaptive Testing" ,*International Journal of Artificial Intelligence in Education*, vol.14, 2004, pp.29-61.

[9] D. Booth, H. Haas, F. McCabe, E. Newcomer, M. Champion, C. Ferris and D. Orchard, "Web Services Architecture", *W3C*, 2004.

[10] L. Srinivasan and J. Treadwell, "An Overview of Service-oriented Architecture, Web Services and Grid Computing", *Hewlett-Packard Technical Information*, 2005.

[11] IEEE LTSC, "Draft Standard for Learning Technology – Learning Technology Systems Architecture (LTSA)", *Learning Technology Standards Committee of the IEEE Computer Society*, IEEE P1484.1-2003, 2003.

[12] M. Meccawy, C. Stewart and H. Ashman, "Adaptive educational hypermedia interoperability and content creation with a web service-based architecture", *International Journal of Learning Technology*, vol. 3(3), 2007, pp. 269-285.

[13] W. Dick and L. Carey, *The Systematic Design of Instruction*, 4th Ed., New York, Harper-Collins, 1996.