System Interoperability Study for Healthcare Information System with Web Services

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Abstract

This paper describes the use of a new distributed middleware technology 'Web Services' in the proposed Healthcare Information System (HIS) to address the issue of system and language interoperability raised from existing Healthcare Information systems. With the development of HISs, hospitals and healthcare institutes have been building their own HISs for processing massive healthcare data, such as, systems built up for hospitals under the NHS (National Health Service) to manage patients' records. Nowadays many healthcare providers are willing to integrate their systems' functions and data for information sharing. This has raised concerns in data transmission, data security, and network limitation. Among these issues, system and language interoperability are one of most obvious issues since data and application integration is not an easy task due to differences in programming languages, system platforms, Database Management Systems (DBMS) used within different systems. As a new distributed middleware technology, Web service brings an ideal solution to the issue of system and language interoperability. Web service has been approved to be very successful in many commercial applications (e.g. Amazon.com, Dell computer, etc.), however it is different to healthcare information system. As the result, Web Service-based Integrated Healthcare Information System (WSIHIS) is proposed to address the interoperability issue of existing HISs but also to introduce this new technology into the healthcare environment.

Keywords: Web service, XML, SOAP, WSDL, UDDI, Healthcare Information System

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Introduction

With the evolution of IT technologies and increasing demands from people for computerising medical-related information, healthcare institutions have developed systems to manage and process the large amount of medical information. In order to achieve information exchanging and medical knowledge sharing, hospitals and healthcare providers have intended to integrate their systems' functions and data. This raised some concerns, such as, data security, data transmission, network limitation and so on [1]. Among these issues, the issue of system and language interoperability are most obvious barrier for the integration of functions and data of different systems. In practice, systems were developed using different languages (e.g. Java, Visual Basic, C++, etc.), different system platforms (e.g. Microsoft Windows operating systems, Linux operating system, etc.) and DBMSs (e.g. Microsoft SQL server, Oracle, Microsoft Access, etc.) [2-5]. These differences between systems are major factors leading to the issue of system and language interoperability. Traditionally, developers use distributed middleware technologies, like CORBA (Common Object Request Broker Architecture)/DCOM (Distributed Component Object Model) to tackle the issue of system and language interoperability. Regarding to the author's research, there have been some of HISs, such as I-HER [3], Hospital Information System [5], BHS [4]. But CORBA/DCOM would become unsuitable while they are applied into those systems based on Internet environment. That is because CORBA/DCOM has the shortcoming in the firewall crossing and wireless environment [6-8]. In addition, CORBA/DCOM is a fairly complex issue, a task requiring special expertise [9]. Nowadays, Web service as a new distributed middleware technology can not only overcome those shortages from CORBA/DCOM but also to successfully address the issue of system and language interoperability. Web service has been successfully applied in many commercial applications, nevertheless, a few of people and organisations formally deployed this technology into healthcare industries. In this paper, a Healthcare Information System named as 'Web Service-based Integrated HIS (WSIHIS)' is proposed and built up with the support of web service and some Microsoft .Net-based technologies to address the issue of system and language interoperability. The main objective of this paper is to illustrate how Web Service and Microsoft .Net technologies are used to deal with the issue of system and language interoperability. Moreover, system interoperability test was carried to assess if whether the web service-based solution is really able to cope with the issue of system and language interoperability.

The issue of interoperability of current HISs

The interoperability can be defined as "the capability with which two or more programs can share and process information irrespective of their implementation language and platform" [5, 10]. Interoperability concerns also rise as one of the most urgent priorities of healthcare information systems [11, 12]. Connecting for health, as a single IT provider for the NHS defined the interoperability issue 'it is impossible for different healthcare information systems to smoothly, seamlessly, privately communicate information when it is needed to where it is needed' [1]. Most clinical applications are determined by a huge variety of heterogeneous and independent work places, most of them equipped with specialised clinical hardware [12]. Usually, different parts of a large-scale telemedicine system might be from various vendors, who use different standards and information formats, such as, National Program for IT (NpfIT) [13]. These systems are also used by people with different levels of expertises and needs. Once the interoperability problem is solved, the development and maintenance of large telemedicine systems can be streamlined with data reuse, code reuse, application reuse and choice of an appropriate computing environment using object-oriented technology. The following content would explain the interoperability problem from different perspectives [5, 10]:

Database System Interoperability: Patient records are often located in different database systems [14]; however, data from different database systems cannot be exchanged with each other and used by applications based on different DBMSs.

Language Interoperability: Usually, different HISs could be developed by different IT providers [15], developers make use of different programming language to built their HISs. This would make the reuse and share of applications between different HISs very hard because of the incompatibility between different programming languages.

System-platform Interoperability: System platform interoperability means OS interoperability, but over the last few years the Internet browser has emerged as a platform in itself [16]. As different HISs could be developed based on different development platforms, this feature would make those HISs only work on some certain system platforms.

Semantic Interoperability: some interoperability problems are caused by semantic differences. Semantic interoperability assumes that the components of the distributed application will have different meanings. Usually human intelligence is required to solve it, however this problem has been beyond the scope of this paper.

The following section would mainly discuss the issue of system and language interoperability based on those systems delivered by the NHS system as a typical example. Within recent years, there is a huge program being delivered by the NHS – National Program For IT (NpfIT). NpfIT was proposed in February 2002, which is aiming to modernise the NHS system with information technologies [17]. In Oct 2002, this program is formally established, which mainly comprises of various healthcare systems for different purposes. It is no doubtful that the interoperability issue is inevitable because of the following reasons:

Different business processes in different ways [18]: There are thousands of hospitals under the NHS, most doing different business processes and having different health systems, which makes NpfIT more complex to interoperate with those various systems.

The requirement for the interoperability between systems delivered by NpfIT: For example, Electronic Transmission Prescription, as one of systems delivered by NpfIT was originally envisaged as a separate system [15]. However, this program will also be required to be integrated with another program of NpfIT 'NHS Care Records Service' [19].

Dozens of different patient-record systems in use across the NHS: There are dozens of different patient-record systems in use across the NHS developed by different software providers [15]. This situation would increase the difficulty for the integration of different records.

Need to interoperate with systems on doctors' desktops [15]: NHS Care Records Service, as one of services of NpfIT will need to interoperate with systems on doctors' desktops. This would be challenging enough if the systems were built from scratch. NpfIT must rely on many existing hospital and GP systems being connected to the spine that is a kind of new database system of NHS [15, 20].

Two separate NHS systems between Scotland and England: Since Scotland and England are using two different NHS systems [21, 22], both of places are also developing two different Healthcare Information Systems with different IT providers. This situation may lead to the potential system interoperability issue if both NHS systems based in England and Scotland are expected to be integrated for some certain purposes.

Furthermore, under the NHS system, most existing IT systems in trusts are based on either buildings or departments [13]. These systems do not usually support the movement of information between buildings and departments. Consequently, within a single organisation, several records are often created for the same patient [13]. Similarly, in primary care, individual practices have their own IT applications and databases, so patient records are not easily transferred to other practices or care providers [13].

The Solution of Interoperability – Web Service

Seamless interoperability with applications and data from different systems is a challenging task. Traditionally, solutions of interoperability normally involve developing middleware applications to communicate the non-interoperable applications using the messages, of which the technology is also named as the distributed middleware technology [9]. CORBA and DCOM are two most typical distributed middleware technologies. Nevertheless, CORBA or DCOM is a fairly complex, a task requiring special expertise. Quite often, the achievement of a good interoperability strategy is significantly constrained by many implementation restrictions in CORBA or DCOM [9, 23, 24]. Web services have emerged as the next generation of integration technology [7, 23, 25]. Based on open standards, the Web services technology allows any piece of software to communicate with each other in a standardised XML messaging systems[6, 9, 23]. It solves and eliminates above issues of DCOM/CORBA [23]. As a new type of software service, Web services are modular self-describing, and self-contained applications that can be published, located, and dynamically invoked across the Web. The Web-services technology is built on the foundation of open standards and common infrastructure. The Web-services framework is divided into three areas – communication protocols, service descriptions, and service discovery, of which each is specified by an open standard [26].

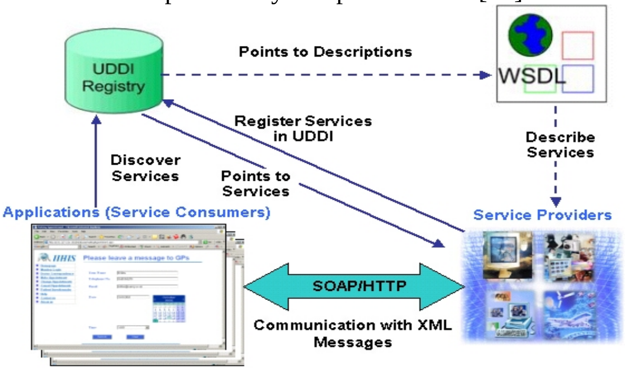


Figure 1. A detailed architecture of Web service

Figure 1 also indicates how web services works. In general, web services consist of two major technologies (XML – extensible Markup Language and SOAP – Simple Object

Access Protocol) and two assistant technologies (WSDL – Web Services Description Language and UDDI – Universal Description, Discovery, and Integration).

- Firstly, service providers would make use of WSDL to describe their web services
- Following the above step, service providers would register and publish their services in UDDI
- Applications or service consumers find services via UDDI which would direct service consumers to relevant services according to the description of web services
- Regarding to previous step, applications or service consumers are able to invoke relevant web services using SOAP transmitted via HTTP on the Internet.

Web services encoded in XML, SOAP provides a way to communicate between applications developed with different programming languages and running on different operating systems. In fact, Web services provide a distributed computing technology for integrating applications on the Internet using open standards and XML encoding. The use of standard XML protocols makes Web services platform-, Language- and vendor-independent, thus an ideal solution for use in application integration.

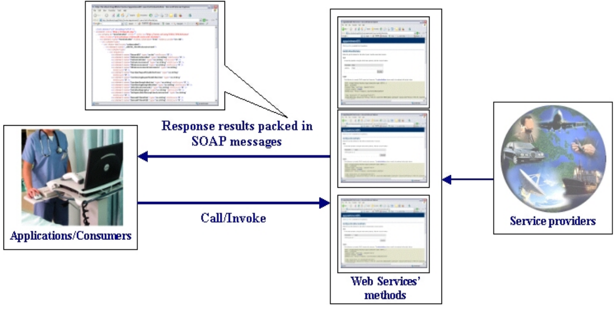


Figure 2. Interaction between applications/consumers and Web services

With respect to the above figure, applications send requests and responses to and from Web services via SOAP. When a program invokes a Web-service method, the request and all relevant information are packaged in a SOAP message and sent to the appropriate destination. When the Web service receives the SOAP message, it begins to process the contents (called the SOAP envelop), which specifies the method that the client wishes to execute and the arguments the client is passing to that method. After the Web service receives this request and parses it, the proper method is called with the specified arguments (if there are any), and the response is sent back to the client in another SOAP message. The client parses the response to retrieve the result of the method call.

<u>Case Study: Web Service-Based Integrated Healthcare Information System (WSIHIS)</u>

Background of WSIHIS

Many people around the world became amputees because of war, traffic accident and some sorts of disease (e.g. Diabetes). Traditionally, these amputees would be treated with conventional socket techniques. With the development of medical technologies, new treatment's techniques for amputees would be based on the Osseointegration that is discovered by Pro. Branenmark. The first Osseointegration surgery is dental implant, and then he brought this technique further in 1990s [27]. Pro. Branenmark applied the Osseointegration in orthopaedics. In 1997, Branenmark chose Queen Mary hospital as the clinical trail outside of Sweden [27]. Basically, this technique makes use of Titanium implant as the attachment site for the artificial limb attachment. Because this is entire new technique, patients would be selected carefully. A scheme called OPRA (Osseointegration Programme for Rehabilitation Amputee) was developed at Sweden that consists of patients' selection and recruitment, surgical plan after surgeon retirement and rehabilitation. The whole procedure of Osseointegration from the operation to the rehabilitation of patients lasts years. Overall, this process would involve doctors, patients, surgeons, prosthetic clinician and rehabilitation clinician. All relevant information must be recorded and documented for progress review. Patients' files are also required if the infection is developed in later stage. They would require an information system to manage and process these massive health data, as the patient, the hospital and the rehabilitation centre and prosthesis are normally not in same location. The data exchange between them would be very important. Consequently, WSIHIS is proposed to computerise all documents and data, and offer a secure and stable environment for the communication between doctors and patients across the Internet.

Interoperability Issue of WSIHIS

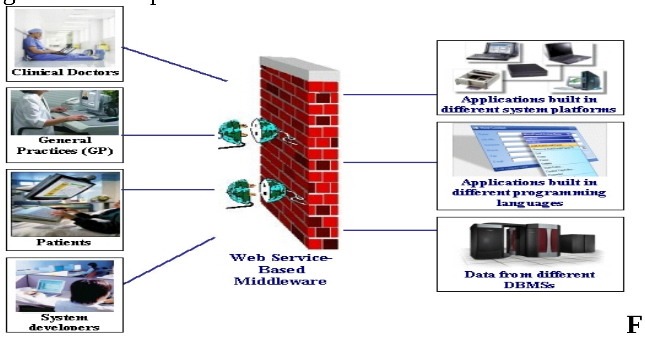
According to the above statement, it is not difficult to find out WSIHIS would also face the challenging of interoperability issue as other HISs. Principally, interoperability issue of WSIHIS could be concluded as follows:

System interoperability issue: Regarding to the description of background, WSIHIS would be required to link with various medical-relevant people (e.g. GP, Surgeon, prosthetic clinician and rehabilitation clinician), who might be using different system on their desktops to access to WSIHIS for different purposes. To achieve this feature, WSIHIS would be required to have the capability to interoperate with those different systems (e.g. Microsoft Windows Systems, Linux Systems, etc). Additionally, some parts of patient records could be produced from some existing systems used by some medical staff (e.g. GP) or even depend on those data from existing healthcare systems. And with the data sharing purpose, WSIHIS would need to interoperate with different DBMSs (e.g. Microsoft SQL server, Oracle, Microsoft Access).

Language interoperability issue: WSIHIS is also expected to be integrated with functions of existing and future healthcare systems. Generally, different systems are built up in different technologies, particularly, different programming languages. For example, there are dozens of different patient-record systems in use across the NHS developed by couples of software providers. In order to enable WSIHIS to be compliant with those functions from different systems, WSIHIS is supposed to interoperate with applications built up in different programming languages, such as, Java, Visual Basic, C++ and C#.

Web Service-Based Solution for Interoperability Issue of WSIHIS

WSIHIS is built up with the support of Web Service to address above interoperability issue. Currently, there are two major application platforms – Microsoft .Net and Java 2 Enterprise Edition (J2EE) being able to create Web services. Microsoft .Net is selected as the major platform for developing the proposed system since Microsoft .Net would be more suitable than J2EE in terms of some features (e.g. overall maturity, interoperability, scalability, cost and the NHS perspective) [5, 28, 29]. Besides, there have also been couples of developers of Healthcare Information Systems expressing the interest to Microsoft .Net for the development of their HIS [2, 5] when Microsoft .Net was not really put into the market. As the result, Microsoft .Net is selected to build up the proposed system. The following figure would illustrate a general concept of Web service-based solution of WSIHIS:


Clinical Doctors
General Practices (GP)
Patients
System developers
Web Service-Based Middleware
Applications built in different system platforms
Applications built in different programming languages
Data from different DBMSs

F

Figure 3. The general concept of Web service-based solution for the interoperability issue of WSIHIS

Within WSIHIS, Web service plays as the role of middleware that hides all these differences in system platforms, programming languages and database systems to users and developers. Accordingly, from users' perspective, they would be able to get the access to WSIHIS regardless of their different system platforms. From developers' perspective, they can invoke or reuse applications of WSIHIS in their systems with the support of web services.

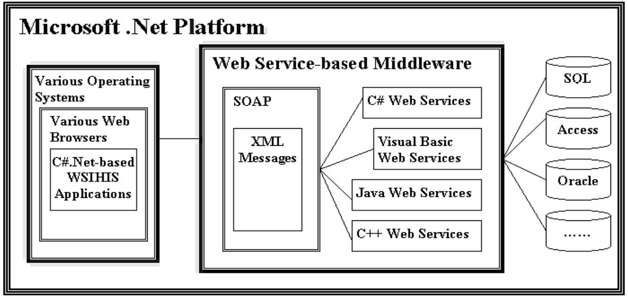


Figure 4. The way of Web service working in WIHIS with the support of Microsoft .Net technologies

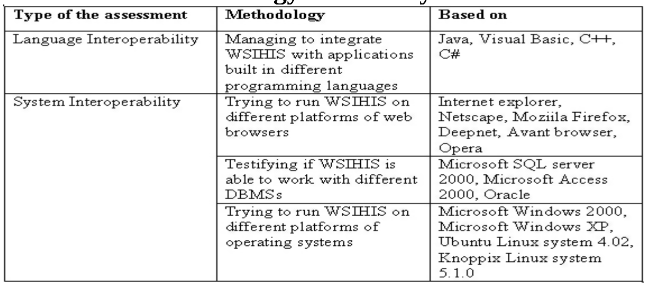
Figure 3 illustrates a general concept of Web service-based solution for the interoperability of WSIHIS. Figure 4 explains how Web Service and Microsoft .Net technology are applied in WSIHIS. WSIHIS is built upon Microsoft .Net platform, and Web service plays a role of middleware. Web services can be exposed from and consumed by any platform that can format and parse an XML message because using XML for the formatting of requests and responses. This allows XML-based Web services to bring together disparate pieces of functionality – exiting or new, internal or external to an organisation – into a coherent whole. Core technologies of Web service are XML and SOAP. Once Web services receive requests from applications, web services would retrieve data from different DBMSs (e.g. SQL server, Microsoft Access, Oracle, etc.) into datasets according to requirements of applications. All datasets would be written in XML messages, in additions, SOAP would act as an XML envelop to wrap those XML-based datasets into SOAP messages. And then these SOAP messages would be transmitted back to applications via HTTP. SOAP in Web service-based middleware provides a way to communicate between applications developed with different programming languages and running on different operating systems.

Additionally, Microsoft .Net platform is another important part of solution for the interoperability in WSIHIS. It is language neutral. It is best thought of as an open programming platform into which a variety of languages can be plugged. It is achieved by translating all different programming languages into a common language called Intermediary Language (IL). Firstly, source code is translated into Microsoft Intermediate Language (MSIL). This IL code is language-neutral, and is analogous to Java bytecode. The IL code then needs to be interpreted and translated into a native executable. The .NET Framework includes the Common Language Runtime (CLR), analogous to the Java Runtime Environment (JRE), which achieves this goal. The CLR is Microsoft's intermediary between .NET developers' source code and the underlying hardware, and all .NET code ultimately runs within the CLR. Regarding to the announcement of Microsoft company [23], Microsoft .Net platform would also enable the system running under different system platforms and web browser platforms.

System Assessment on the interoperability of WSIHIS

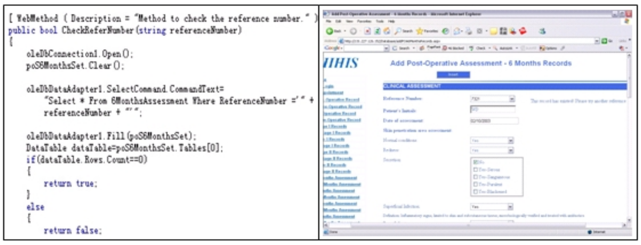
The assessment has been done to testify whether Web service and Microsoft .Net technologies could really enable WSIHIS to overcome or eliminate the interoperability issue. The following part would make an analysis and discussion based on the result of assessment. The methodology used for system assessment is shown as the following table:

Table 1. The methodology of whole system assessment



Type of the assessment	Methodology	Based on
Language Interoperability	Managing to integrate WSIHIS with applications built in different programming languages	Java, Visual Basic, C++, C#
System Interoperability	Trying to run WSIHIS on different platforms of web browsers	Internet explorer, Netscape, Moziila Firefox, Deepnet, Avant browser, Opera
	Testifying if WSIHIS is able to work with different DBMSs	Microsoft SQL server 2000, Microsoft Access 2000, Oracle
	Trying to run WSIHIS on different platforms of operating systems	Microsoft Windows 2000, Microsoft Windows XP, Ubuntu Linux system 4.02, Knoppix Linux system 5.1.0

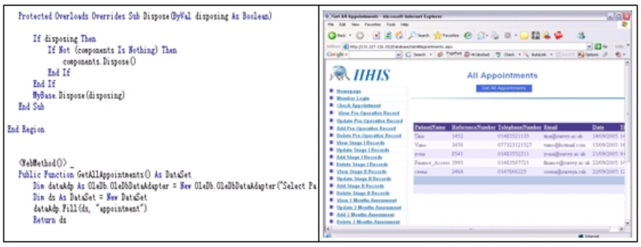
Regarding to the assessment of language interoperability, four comparable Web service-based applications were built up in different programming languages (C#, Visual Basic, Java, C++). The purpose of assessment is to integrate four applications with WSIHIS to achieve given tasks. The C# application is aiming to validate the reference number entered by the user. With this application, WSIHIS would display the error message for any invalid reference numbers entered by users. The code and resulting screen is shown in Figure 5.



```
[ WebMethod ( Description = "Method to check the reference number." )]
public bool CheckReferNumber(string referenceNumber)
{
    oleDbConnection1.Open();
    poS6MonthsSet.Clear();

    oleDbDataAdapter1.SelectCommand.CommandText=
        "Select * From 6MonthsAssessment Where ReferenceNumber ='" +
        referenceNumber + "'";

    oleDbDataAdapter1.Fill(poS6MonthsSet);
    DataTable dataTable=poS6MonthsSet.Tables[0];
    if(dataTable.Rows.Count==0)
    {
        return true;
    }
    else
    {
        return false;
```

Figure 5. The code and screenshot of application in C#

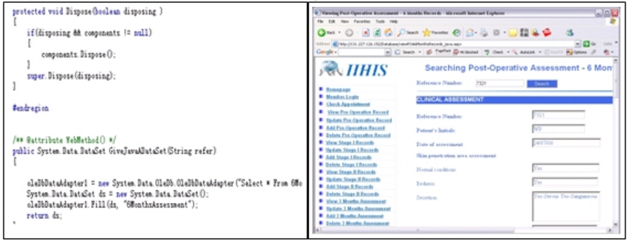
In WSIHIS, there is a function named as 'Check Appointments' aiming to help doctors search appointments' records made by patients via reference numbers. Nevertheless, if the doctor forgets the reference number of patient, he would be unable to find the appointment record. Regarding to this reason, another function coded in Visual Basic was developed to enable the system display all appointments' records. Figure 6 illustrates the code and screenshot of this application.



```
  Protected Overloads Overrides Sub Dispose(ByVal disposing As Boolean)

      If disposing Then
          If Not (components Is Nothing) Then
              components.Dispose()
          End If
      End If
      MyBase.Dispose(disposing)
  End Sub

End Region


  <WebMethod()> _
  Public Function GetAllAppointments() As DataSet
      Dim dataAdp As OleDb.OleDbDataAdapter = New OleDb.OleDbDataAdapter("Select Pa
      Dim ds As DataSet = New DataSet
      dataAdp.Fill(ds, "appointment")
      Return ds
```

Figure 6. The code and screenshot of application in Visual Basic

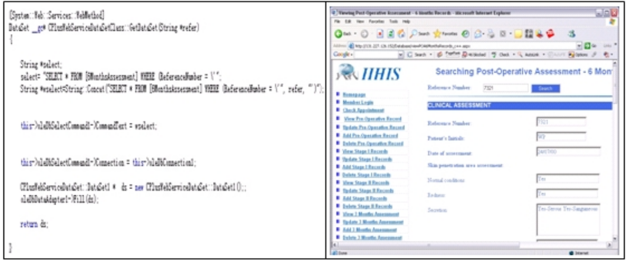
Another application is developed in Java that is aiming to assist WSIHIS to find a relevant patient record via a reference number, of which the code and screenshot of application is illustrated in figure 7.



```
protected void Dispose(boolean disposing )
{
    if(disposing && components != null)
    {
        components.Dispose();
    }
    super.Dispose(disposing);
}

#endregion


/** @attribute WebMethod() */
public System.Data.DataSet GiveJavaADataSet(String refer)
{

    oleDbDataAdapter1 = new System.Data.OleDb.OleDbDataAdapter("Select * From 6Mo
    System.Data.DataSet ds = new System.Data.DataSet();
    oleDbDataAdapter1.Fill(ds, "6MonthsAssessment");
    return ds;
```

Figure 7. The code and screenshot of application in Java

The function of application in C++ is same as the application in Java that is to retrieve patient records through reference numbers. Its code and resulting screen is shown in Figure 8.



```
[System::Web::Services::WebMethod]
DataSet __gc* CPlusWebServiceDataSetClass::GetDataSet(String *refer)
{

    String *select;
    select= "SELECT * FROM [6MonthsAssessment] WHERE (ReferenceNumber = \'";
    String *wselect=String::Concat("SELECT * FROM [6MonthsAssessment] WHERE (ReferenceNumber = \'", refer, "')");


    this->oleDbSelectCommand1->CommandText = wselect;


    this->oleDbSelectCommand1->Connection = this->oleDbConnection1;

    CPlusWebServiceDataSet::DataSet1 * ds = new CPlusWebServiceDataSet::DataSet1();;
    oleDbDataAdapter1->Fill(ds);

    return ds;

}
```

Figure 8. The code and screenshot of application in C++

The assessment of system interoperability comprises of testing the system on different web browsers, different DBMSs and different operating systems. Firstly, this assessment focuses on testing the interoperability of WSIHIS with six selected web browsers (Internet Explorer, Opera, Mozilla FireFox, Deepnet Browser, Avant Browser and NetScape), on which the author runs WSIHIS to execute specific tasks (e.g. making appointments, changing appointments, etc.) to see if WSIHIS is able to run regardless of different web browsers, of which the result has proved the proposed system has no problems on this point, as illustrated in figure 9.

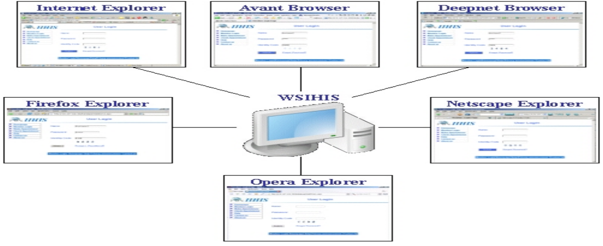


Figure 9. The result of Web Browsers' platform interoperability Testing of WSIHIS

Secondly, the assessment is to testify the ability of WSIHIS for integrating different applications linked with three different DBMSs (Microsoft Access, Microsoft SQL Server, Oracle), and the result of this assessment verified that the system is able to interoperate with applications based on different DBMSs, as shown in figure 10.

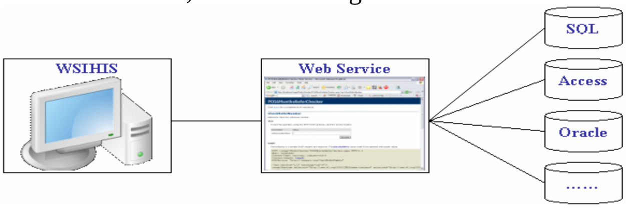


Figure 10. The result of DBMS platform interoperability Testing of WSIHIS

Finally, the assessment emphasises on testing the capability of WSIHIS running on different operating systems (Microsoft operating systems and Linux operating systems). WSIHIS was given specific tasks to carry out (e.g. making appointments, searching patients' records). The result of the assessment proved that the proposed system has no problem to work on any different operating systems, as shown in figure 11.

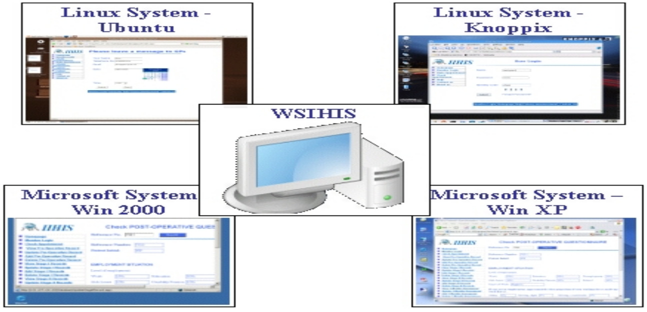


Figure 11. The result of system platform interoperability Testing of WSIHIS

Discussion and Conclusion

System and language interoperability of HISs is a major concern in this paper. Web services provide an ideal solution for this concern. However, people may question why system and language interoperability is so critical for HISs and why HISs should have the interoperability rather than just stick with the single technology, DBMS and system platform. Actually, HISs under the NHS in U.K, as an example, are spread over the whole country. Historically, these HISs were developed by different software providers with different programming languages, different system platforms and database systems. Within a single hospital, several records are often created for the same patient; on the other hand, patient records are often located in different database systems. In primary care, individual practices have their own IT applications and databases, so patient records are not easily transferred to other practices or care providers. Today, NHS is developing NpfIT to integrate separated HISs for sharing medical information and functions. The first requirement for this purpose is to enable different HISs to interoperate in a seamless environment regardless of the programming languages, operating systems and database systems. Major benefits from the achievement of interoperability can be concluded from several aspects. Firstly, for existing HISs, medical data and functions can be easily shared and exchanged between different HISs, additionally, systems would be accessible to people using different operating systems. Secondly, for those HISs under the expansion and improvement, new technologies can be easily plugged into original systems. Finally, for those HISs under the development, they can reuse functions from other HISs to reduce the development time scale and cost.

The main contribution of this work is the introduction and use of Web service to achieve system and language interoperability of HISs in a heterogeneous environment. The implementation of WSIHIS has already been carried out based on the background of Osseointegration project in Queen Marry hospital. Within WSIHIS, Web service acts as a distributed middleware to facilitate the interoperability of the whole system with the support of Microsoft .Net technologies. An overall assessment was also executed to test how well WSIHIS to address the interoperability problem with the support of web service and Microsoft .Net technologies. This assessment consists of testing WSIHIS on applications developed in diverse programming languages, system platforms and database systems. Its result shows the application of web service and Microsoft .Net technologies in WSIHIS is very promising and offers more benefits on enhancing the interoperability of system. Another assessment will be carried out based on the wireless environment. This will enable the author to measure how well WSIHIS works and interoperate with other HISs under the wireless environment.

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