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EXPERT-SYSTEM-BASED INTERPRETATION OF HEPATITIS SEROLOGY TEST RESULTS AS APP STORE IPHONE APPLICATION

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Abstract

The availability and use of mobile devices and services have increased significantly in the last few years. The advantages of mobile applications are numerous: they are nearly always available, not bound to a specific location, and generally easy to use. Hepaxpert is a medical expert system for automated interpretation of the outcome of hepatitis serology testing. The system provides clinically oriented interpretive texts for any combination of hepatitis serology test results (more than 60,000 combinations exist for hepatitis B). It is currently available as a web-based system with an HTML client, and has been redeveloped as a mobile iPhone client application. The success of this innovation depends on simultaneous reprogramming and extension of the existing Hepaxpert software to a state-of-the-art mobile application using web services. The result was an easy-to-use iPhone application with an input screen for serological test results and an output screen displaying the interpretive report.

***Keywords* – Hepatitis serology test results, Expert-based interpretive analysis, Mobile application, App Store, iPhone**

1. Introduction

Expert systems are being increasingly used in medical environments such as hospitals, laboratories, and intensive care units, with a view to improving the quality of health care and reducing the likelihood of incorrect medical decisions. Transformation of these systems into mobile solutions would extend their benefits and facilitate their integration into medical environments.

New generations of mobile devices offer users new modes of interaction with medical expert systems. Our approach involves the use of a mobile client-server model employing web services in order to transfer the currently available web-based system Hepaxpert with HTML client [9] onto a new platform. The server is dedicated to provide an interpretive report of the obtained test results, whereas the client acts as a convenient user front-end. Communication between the client and the server is based on web services.

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1. 1. Hepaxpert

Hepaxpert, a knowledge-based medical expert system, was originally developed in 1989 and has been described in [4-6].

The goal was to automatically interpret the test results of hepatitis A, B, and C serology, and obtain a textual interpretation of the test results. Further tests are suggested if necessary. The availability of these interpretations saves valuable time for the clinician and provides detailed information even for the non-hepatitis serology expert.

The tests for hepatitis A serology measure antibodies to the hepatitis A virus (anti-HAV), immunoglobulin M antibodies to the hepatitis A virus (IgM anti-HAV), and the hepatitis A virus in stool (HAV-RNA). For hepatitis B serology, the tests measure the surface antigen and antibody to hepatitis B (HBsAg and anti-HBs), antibodies to the core antigen (anti-HBc and IgM anti-HBc), and the envelope antigen and antibody (HBeAg and anti-HBe). The anti-HBs titer was subsequently added to the hepatitis B test, which yields a quantitative measure of antibodies to the antigen of the hepatitis B virus. If a person has been vaccinated against hepatitis B, the test indicates the level of antibodies still present and suggests re-immunization if necessary. The tests for hepatitis C serology indicate antibodies to the hepatitis C virus (anti-HCV) and the HCV-antigen (HCV-RNA).

One of four results may be obtained for each of these tests: positive, negative, borderline, or not tested. Accordingly, 64 possible combinations exist for hepatitis A serology, 4,096 for hepatitis B, and 16 for hepatitis C. Addition of the anti-HBs titer test to hepatitis B serology would increase the number of possible combinations for hepatitis B to 61,440.

1. 2. Arden Syntax

Arden Syntax [8] is a medical knowledge representation scheme whose definition and further development are supported by the Health Level Seven (HL7) organization. Arden Syntax has been approved as standard by the American National Standards Institute (ANSI), and uses medical logical modules (MLMs) as the smallest units to represent clinical knowledge. In the Arden-Syntax-based Hepaxpert system, these MLMs contain rule sets for the interpretation of hepatitis serology tests, albeit in a highly condensed form. To implement these MLMs we used the Arden Syntax software developed by Medexter Healthcare. The implementation consists of an Arden Syntax compiler, an Arden Syntax engine (Arden Syntax runtime), an Arden Syntax server, interfaces, and a development environment. The Arden Syntax compiler converts MLM files into a binary representation that is then executed by the engine.

2. Methods

2. 1. Systems architecture

The systems architecture (see *Figure 1*) consists of a Java-EE-based application server which exposes a secured web service to the cloud. RESTful clients connect to the interface to obtain the interpretive report of the given laboratory test results. A mobile iPhone client was designed to serve as client, and extended the existing web-based Hepaxpert system.

2. 2. Server

We implemented a state-of-the-art Java application server based on Java Platform, Enterprise Edition (Java EE), using Java 6 as programming language. The Java application server offers a representational state transfer (RESTful) [14] web service library, which can be used as an endpoint for various clients. We decided to use RESTful web services instead of the service-oriented architecture protocol (SOAP) [16] or remote procedure call (RPC) [12]-based communication methods, because Apple's support for such web services is limited at this point in time. Besides, the implementation of RESTful services is technically simpler because it uses standard hypertext transfer protocol (HTTP) methods such as GET, POST, PUT and DELETE. The simple JavaScript object notation (JSON) encapsulated in an HTTP POST request [10] was selected as the communication data format. This decision permitted straightforward implementation on both sides: the server as well as the client.

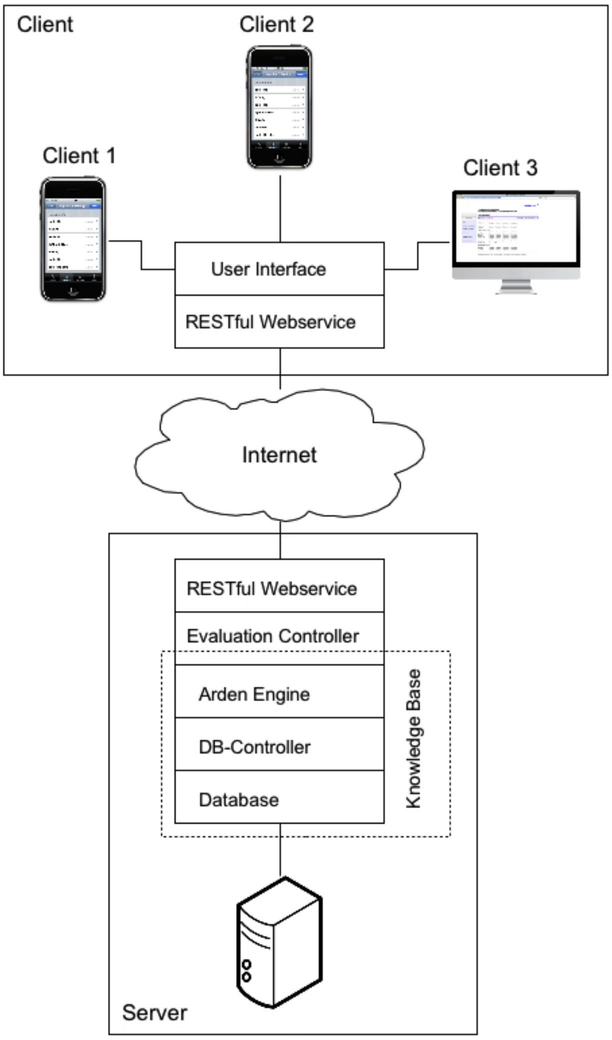

Figure 1: Systems architecture of the App Store iPhone Hepaxpert

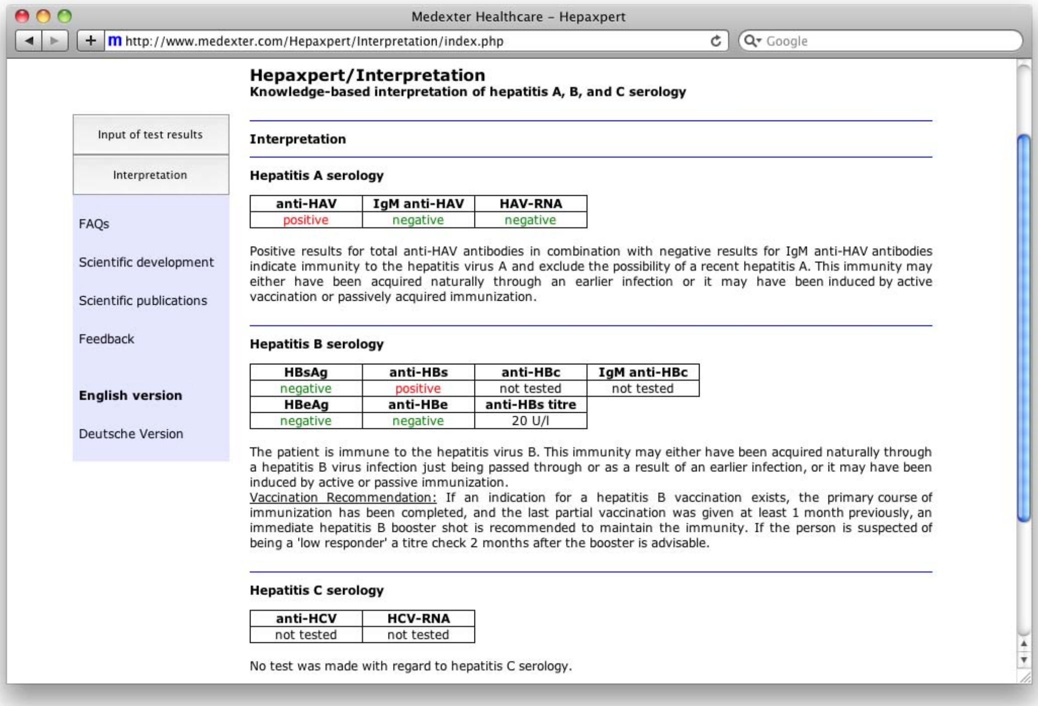

Figure 2: Interpretive results of the existing Hepaxpert Web Application

Figure 3: Input and Interpretive result on the iPhone client

2. 3. Client

Selection of the mobile platform to be used was based on the following criteria: distribution of the mobile platform, processing power, programmability, and efficient software distribution. Currently, Apple with its iPhone App Store is the largest provider of mobile applications. More than 100,000 applications were available at the beginning of 2010 [1], and more than three billion downloads have been registered [3]. According to the recently released MobiHealthNews 2010 Report [11], nearly 6,000 mobile medical applications are available for smartphones. A large number of them have been released in the past six months. About 87 percent of these applications are available on the iPhone, which makes it an excellent platform for the distribution of Hepaxpert.

The first and major task in developing the Hepaxpert iPhone client was to define a flexible, user friendly and intuitive user interface. Apple's mobile human interface guidelines [2] were a good start. Apart from design, the resource limitations on the iPhone were the next challenge. This concerns hardware as well as software. The goal was to transfer the entire functionality of the existing HTML-based web application (see *Figure 2*) to the much smaller mobile iPhone screen (see *Figure 3*). We had to reconsider the single screen concept in which the three types of serology (hepatitis A, B, and C) are presented on one screen, and redesign the user interface so that every hepatitis serology interpretation appears on a separate screen. Data input selection had to be shifted to an additional iPhone screen.

In order to shift easily between the different hepatitis serology types, we decided to implement a well-known design pattern for iPhone applications: the Tab Bar. This element is always visible at the bottom of the screen. To switch between the overview and input (see *Figure 3*) screen we implemented a navigation controller bar on the top of the screen. If the user taps on an input cell, the selection screen appears. When an option is selected, the user automatically returns to the overview screen. To view the interpretation, the user touches the "submit" button which results in a web service call to the server, and displays the obtained results (see *Figure 3*).

3. Discussion and conclusion

Although a large number of medical iPhone applications are available in Apple's App Store, medical expert or decision support systems are scarce. As reported in [11], about 30 percent of all medical mobile applications have been designed for medical professionals or medical students, and primarily focus on well known references such as the iPhone App "Pschyrembel" [15]. Our system, Hepaxpert, does not merely provide static textual information [13] for the user but also evaluates medical data through a clinical decision support rule engine.

Implementation of the iPhone client for Hepaxpert shows how an online-based system can be ported to a mobile platform. An important aspect of implementing a mobile application is to focus on an iterative development process [7]. In addition, users within the mobile community are able to provide valuable feedback through the iPhone App Store as well as via e-mail. Thus, the development of mobile software as well as the knowledge base is an ongoing process. Future versions will be significantly influenced by the users.

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