Dental Application: The Steps toward the Implementation of the CephSmile Plus Services

Chanjira Sinthanayothin, Wisarut Bholsithi

Abstract

Software Plus Services will be the next step in the evolution of computing with a concept of Software as a Service (SaaS) to complement the existing packaged software by running for both client and server with services adding value. CephSmile V2 is a dental application software program for 2D cephalometric analysis, dental model analysis focusing on orthodontic treatment planning applied to simulate changes on the facial profile after receiving treatment. CephSmile V2 could be applied to analyze craniofacial growth changes leading to skeletal discrepancies and to study the causes of malocclusions. Since CephSmile V2 is intended to be commercialized as services known as CephSmile Plus Services, the program has been developed to access the web database. Two main steps develop the CephSmile Plus Services. The first step is the CephSmile V2 Program development with six main features to be described as follows: Lateral Cephalometric Analysis, Superimposition, Orthodontic Treatment Simulation, PA Cephalometric Analysis, 3D Skull Simulation from 2D x-ray views and Dental Model Analysis. The second step is the CephSmile Plus Services implementation, divided into two main sections: The first section is the web database. The second is the V2 program to connect with the online database following the REST guidelines using GET and POST methods with the additional reverse engineering deterrent. This is done by applying executable compression via a portable executable packer. The result shows that CephSmile V2 can be used as a diagnostic tool for orthodontic treatment and simulation which requires a username/password to login to the database. The result also demonstrates the details of the login user to use the CephSmile V2 program in terms of amount of hours, number of usages, and functions that the user has been accessing. Also, the administrator is allowed to create a user account and setup the capabilities of the user level in different packages: silver, gold, platinum, and titanium packages. It is concluded that CephSmile Plus Services can be provided to the orthodontist community as software plus services.

Keywords: Software as a Service, Cephalometric Analysis, Executable Compression

1. Introduction

For many years our lives, our businesses, and our social communities have been transformed by the World Wide Web (WWW) technology. Software Plus Services [1-2], first introduced by Microsoft, will be the next step in the computing evolution by the combination of hosted network services and locally running software application. It describes composite applications created by combining traditional software with remote network services to provide a consistent and seamlessly integrated user experience across devices and form factors. Software Plus Services is a concept where Software as a Service (SaaS) [3] complements the existing packaged software running for both client and server by services adding value. One hope is that web services will enable cross-organizational applications that are at the heart of e-Business and e-Government. Web services taking place in society. It includes the goal of making it possible to link programs and data from various sources including WWW with ease in a way that creates a new look of the data or even a new application. Web service is a topic that has garnered a lot of attention in the last few years. Currently two ways of thought shape the development of web services: the traditional, standards-based approach SOAP (Simple Object Access Protocol) and conceptually simpler and the trendier new kid on the block REST (Representation State Transfer) [4].

CephSmile V2 [5] is dental application software for 2D cephalometric analysis, dental model analysis focusing on orthodontic treatment planning applied to simulate changes on the facial profile.
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after receiving treatment. CephSmile could be used to analyze craniofacial growth changes that lead to skeletal discrepancies and to study the cause of malocclusions. The first version of CephSmile has become commercial software, available on the market since 2006 and a studying tool at the Department of Orthodontics, Mahidol University. CephSmile V1.0 has been sold as a single license with a hard lock for security protection. For the second version of CephSmile, the graphic user interface (GUI) is much more attractive, convenient and easy to use. Also, more functions have been added and the previous features have been enhanced for better analysis results as well.

The most important feature of CephSmile is the cephalometric analysis function, a standard procedure for orthodontic measurements. Furthermore, two-dimensional cephalometric measurements on both lateral and frontal cephalograms have been extensively studied to diagnose the abnormalities on skull bone and facial tissue with the study results being applied as tools for an appropriate treatment plan by clinicians as well. Several cephalometric analysis software applications with similar features to CephSmile are available including OrisCeph® Rx3 by Elite computer Italia S.A. [6], OnyxCeph™ by Image Instruments GmbH, just recently launched, OnyxCeph 3TM using 3D image information from CT scan in addition to 2D radiographic images and photographic images [7], Dolphin Imaging [8], Quick Ceph Studio® by Quick Ceph System Inc. [9], Dr. Ceph by For Your Imaging Technologies [10], WinCeph® Ver. 8 by Rise Corporation [11] and so on. Now, OrisCeph® Rx3, OnyxCeph 3TM has started to offer online service via internet, after cephX by cephX Inc [12] that offers online cephalometric analysis function service requiring internet connections continuously while running since cephX has been developed as a web application. Therefore, software plus service is probably because users don’t need to connect to the internet all the time. Also, software plus services is better to use in the rural area where the internet is not stable or available. Since CephSmile V2.0 is intended to be sold as services or so called CephSmile Plus Services, access to the web database has been developed.

2. The Development of CephSmile V2

CephSmile V2 is Windows-based 2D & 3D computer graphic aided planning software for orthodontic diagnosis and treatment, which allows users to perform the lateral, PA cephalometric analysis, dental model analysis and facial treatment simulation by the tools provided in this software. CephSmile V2 is written in C language and developed using Borland C++ Builder with the combination of image processing technology and OpenGL. CephSmile V2 has been designed for dental clinicians to perform cephalometric analysis with different types of analysis, both National Analyses (Mahidol, Chula, Chiangmai, Songkhla, Khonkaen) and International Analyses such as Down, Steiner, Tweed, Jaraback, Harvold, Rickette, McNamara and Sassouni Analysis which are significant data showing the structural problems on the skull, face, and teeth. CephSmile V2 has the main features as follow:

2.1. Cephalometric Lateral Analyses [13]
The CephSmile V2 Program is able to perform curve fitting, and smooth the trace lines using a few landmarks before calculating the angles and distances according to trigonometric rules, and comparing the results with the standard cephalometric values for Thai people. CephSmile can perform cephalometric analysis as shown in Figure 1 with different types of analysis including Mahidol, Chula, Khonkaen, Songkhla, Chiangmai, Down, Steiner, Tweed, Jaraback, Harvold, Rickette, McNamara ABO, and Sassouni, whose data from different types of cephalometric analyses indicate the structural problems on the skull, facial profile, and malocclusion of the teeth.

2.2. Superimposition

Figure 2. Superimposition Result from CephSmile V2

CephSmile V2 is also able to record the analysis data before displaying the recorded data using the Superimposition Program to compare the pre- and post orthodontic operation results. This function can show comparative changes on the facial profile as well as dental structure during the orthodontic treatment periods, so the patient can view changes as time passes as shown in Figure 2.

2.3. PA Analysis [13]

Figure 3. Postero-Anterior (PA) Cephalometric Results from CephSmile V2

CephSmile V2 can perform the frontal PA Cephalometric Analysis for facial symmetry analyses and complete the cephalometric analysis process. The PA Analysis of CephSmile also has a function to perform curve fittings, smoothing the trace lines using only few landmarks before calculating the distances according to trigonometric rules and then comparing the symmetrical analysis results relative to various reference axes as displayed in Figure 3.

2.4. Orthodontic Treatment Simulation [14]

CephSmile V2 can determine and simulate dental and facial changes on a patient’s face after
orthodontic treatment. With this simulation, the patients are allowed to see the post-treatment facial structure before the actual orthodontic treatment has been executed as shown in Figure 4(A) while Figure 4(B) shows the treatment simulation result. Therefore, the patient who needs to wear dental braces to correct the dental positions would find the treatment more informative and useful.

2.5. 3D Skull from Lateral-PA X-ray 2D Projections [15]

Since X-ray images can be obtained by relative ease from clinical procedure, CephSmile V2 has presented the technique on 3D skull simulation based on 2D projections as a substitute for the expensive CT scan. CephSmile can perform the simulation of the 3D skull by only applying inexpensive X-Ray images, including lateral and PA views along with the corresponding cephalometric landmarks and line tracings. The result of the 3D simulation can be seen in Figure 5.

2.6. Dental Model Analysis [16]
CephSmile V2 can perform 2D Digital Model Analysis and Planning, including Bolton Analysis on the dental width ratio between the maxillary sums and the mandibular sums dental widths, and dental arch parameters along with dental segmentation before performing orthodontic simulation as shown in Figure 6. CephSmile V2 also has been approved by the Ethic Committee for clinical trial in the project “Study of the Accuracy and Reliability of CephSmile Program Version 2” by the Faculty of Dentistry, Mahidol University, Thailand June 23, 2009.

3. Implementation of CephSmile Plus Services

For the CephSmile plus Services implementation, two main steps need to be executed. The first is web database development using PHP and MySQL and the second step is the CephSmile V2 Program refinement to connect with the database via the network following the REST guidelines using GET and POST methods along with executable compression encryption as a deterrent against the disassembly of the CephSmile V2 Program.

3.1. The Development of CephSmile V2 Database

The CephSmile V2 web database has been designed and located at cephsmilev2.com with the online database available only for members with login names and passwords to access via WWW or the CephSmile V2 Program with the web database system shown in Figure 7. Figure 8 shows the flowchart of the activity for member login and connection to the database. All the user log information such as username, password, date, time, IP address, function code, register id, and so on are recorded and checked against the database for issuing the user authorization to access the information from the website. This information will be analyzed by the system and report about program usage during the specified date to both the administrator and users. The rough class diagram of the CephSmile V2 database, describing the structure of the system, is shown in Figure 9.
3.2. Developing the CephSmile V2 Program to Connect to the Database via the Network

To connect to the CephSmile V2 program with the cephalometric database via the network, it is necessary to enable CephSmile V2 to send the encoded message and receive the encoded response from the online database for data security purposes. After that, further security measures have been added to deter online piracy or other intellectual property infringements. The details can be explained as follows:

![Figure 9. The Class Diagram of the CephSmile V2 Database with the System Structure Description](image)

3.2.1. Sending Messages and Receiving Responses via POST

For further development, the Internet Direct (Indy) components have been applied for connecting to the database via the network. Internet Direct (Indy) is an open source internet component suite based on the blocking socket model including TCP, UDP, and raw sockets for both clients and servers, comprising popular internet protocols such as SMTP, POP3, NNTP, and HTTP, etc. The Internet Direct (Indy) components have been written in Delphi with VCL.Net to be compatible with Visual Studio.Net [17]. Fortunately, the Indy socket component is also included in the Borland C++ Builder even though it is an older version compared with the latest version available online. The TIdHttp component of Indy has been applied to implement an HTTP client and allow access to the website. The simple code shown below attempts to POST data to the website and receive a response. Then the message from the program needs to be counterchecked for authentication every time it is running.

In addition, the TIdTCPClient component has been applied to establish the TCP client connection requiring initialization from the TIdSocksInfo component to implement SOCKS protocol support for Indy clients including the TIdTCPClient and TIdIOHandlerStack component to implement the handler for TIOHandler class variables using socket handles with connection timeouts, a critical function for asynchronous internet connection. The successful connection with the TCP/IP protocol exists after TIdTCPClient component calls Connect() to provoke Open() event to allocate buffers and reset state properties used in TIOHandler class variables. The source code for the implementation of TIdTCPClient/ TIdHttp component is shown below with IdTCPClient1 as the TIdTCPClient component, IdIOHandlerStack1 as the TIdIOHandlerStack component, and IdSocksInfo1 as a TIdSocksInfo component and IdHttp1 as a TIdHttp:

```plaintext
IdTCPClient1->Host = CheckWeb;  // The Client website to be connected
IdTCPClient1->Port = CLIENT_PORT;  // the internet port of Client website to be connected
IdTCPClient1->ConnectTimeout = CONNECT_TIME; // Set ConnectTimeOut to IOHandler for asynchronous connection
IdTCPClient1->ReadTimeout = READ_TIME;   // Set ReadTimeOut for reading for IOHandler
IdSocksInfo1->IPVersion = Id_IPv4;             // Set IPVersion for Sockets Info
IdIOHandlerStack1->TransparentProxy->Assign(IdSocksInfo1); // TransparentProxy of IdIOHandlerStack1
IdTCPClient1->IOHandler = IdIOHandlerStack1; // Initialize IOHandler of TIdTCPClient1 by IdIOHandlerStack
IdTCPClient1->Connect();
bool test = IdTCPClient1->Connected();
```

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if(test == false) {
    // Displaying error message for Connection time out
} else if (test == true) {
    IdTCPClient1->Disconnect();
    // C++ code for POST data to the website and receive a response.
    data->Values["username"] = user;
    data->Values["password"] = pass;
    data->Values["timestamp"] = dateime;
    IdHTTP1->Request->ContentType = "application/x-www-form-urlencoded";
    IdHTTP1->Post(Trim(web), data, Receive);
    Receive->Seek(0, 0);
    Memo1->Lines->LoadFromStream(Receive);
}

3.2.2. Encoding/Decoding Messages

Apart from the procedure on POST data to the website and reception of the user response, the Encode/Decode message transferred via the network should also be done for security issues as well. Some popular encode/decode algorithms are available including Encode/Decode of Base64 [18], Base85 (ASCII 85 binary to text encoder) [19], URL [20] and only encoding algorithms e.g., MD4 hash [21], MD5 hash [22], and SHA1 hash [23] with encoder/decoder algorithm examples and the encoder string shown in Table 1.

<table>
<thead>
<tr>
<th>Encoder Algorithms</th>
<th>Encoder String</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base64 Encode</td>
<td>Q2hhbmppcmEgU2udGhhbmF5b3RoW4=</td>
</tr>
<tr>
<td>Base85 Encode</td>
<td>&lt;-6YKnGC2%][+B)ulFD,*#@&lt;ld5BPD&gt;=</td>
</tr>
<tr>
<td>URL Encode</td>
<td>Chanjira+Sinthanayothin</td>
</tr>
<tr>
<td>MD4 hash</td>
<td>728153451b787f55e8c3d440da75d827</td>
</tr>
<tr>
<td>MD5 hash</td>
<td>400992611d046ade4befe77cbde1763</td>
</tr>
<tr>
<td>SHA1 hash</td>
<td>8cc56a1138a3c272828395e5295a45da65857beb</td>
</tr>
</tbody>
</table>

3.2.3. Modification of Windows Registry

For security reasons, the CephSmile V2 Program has to send values to be updated every time the program is running as a deterrent against message duplication by hackers, planning to apply duplicated messages for user authentication. This can be done by modifying the windows registry, the configuration information storage of window programs in window database created from thousands of setting values. These setting values are categorized in a tree of folders called keys. Setting values are inserted inside keys [25]. Registry can be viewed and edited by calling the regedit.exe utility program of Windows. For this paper, the registry has to be accessed and edited using the CephSmile V2 Program. The example of C-code for updating the value in registry is shown below.

```c
#include <Registry.hpp>
TRegistry *Reg_no;
int __fastcall CheckReg_no()
{
    Reg = new TRegistry;
    Reg->RootKey = HKEY_CURRENT_USER;
    if(Reg->OpenKey("SOFTWARE\xxx\", true))
    {
        if(Reg->ValueExists("First Run"))
        {
            reg_no = Reg->ReadInteger("First Run"); // Check if the Value
            reg_no++;
            Reg->WriteInteger("First Run", reg_no);
        }
    }
}
```
3.2.4. Receiving Message from the Server and Checking Authentication

Authentication is the act of establishing or confirming someone or something as authentic by proving the claims made by or about the subject as true [26][27]. Normally, authentication is evaluated at a server side by checking the username and password to identity a person. However, to protect the database from being copied into the localhost by activating the program through the duplication of the authentication message, a continuously updates message should be sent from the server to the program for authentication as well. In the CephSmile V2 Program, the strings of characters or so-called match password having been set to cover ten years are prepared for 120 strings (one string/month). These match password strings are only known by the administrator, who takes responsibility to update the match password in the web database every month. Moreover, the date/time when the program is running should be compared between the server date/time and client date/time as well to ensure that a client program is a trusted one.

3.2.5. Reverse Engineering Deterrent by Applying Executable Compression via Portable Executable Packer

To protect the execution file from being detected by packet analyzers or a sniffer [28] before performing the reverse engineering process by disassemblers [29], executable compression [30] has been applied in the CephSmile V2 Program to obfuscate [31] the contents of the executable file from being under direct disassembly by encrypting the special code after creating the executable compression file from the original program to make the compressed executable program much more difficult for disassemblers to understand. In this case, the executable compression process has been applied to the CephSmile V2 Program using ASProtect from ASPack [32], a portable executable packer [33] as shown in Fig. 10.

4. Results

During Cephsmile V2 Program development, the program underwent evaluation by studies on both the accuracy and precision of CephSmile V2 in all functions dealing with the measurements by Mahidol University compared to manual methods. The results showed no significant differences using the Cephsmile V2 in comparison with manual tracing results with a p-value greater than 0.05. Therefore, CephSmileV2 can be used as a diagnostic tool for orthodontic treatment and simulation.
To implement CephSmile Plus Services, the web database and all messages, sent and received via POST from the program, must work well. The examples of user account reports are shown in Figures 11(A) and 11(B) displaying the date/time and corresponding function details when users accessed the program and passed information to the database via the program.

The results from the Dede disassembler [34] before applying ASProtect on the executable file of CephSmile V2 is displayed in Figure 12(A) and the result from the Dede Disassembler after applying ASProtect is displayed as an empty page without any assembly codes as shown in Figure 12(B), a protection for the CephSmile V2 Program.

The results from the IDA Pro interactive disassembler by Hex-Rays SA [35] before applying ASProtect on the CephSmile V2 execution file is displayed in Figure 13(A) while the result from the IDA Pro interactive disassembler after applying ASProtect is displayed in Figure 13(B) showing the obfuscated codes read and displayed by the IDA Pro interactive disassembler, an example of the protection built in the CephSmile V2 Program.

Figure 11. User Account Report Example Showing (A) the Database Access Date/Time (B) Functions Accessed by the User along with Time Durations Spent on the Corresponding Functions

Figure 12. Obfuscation Results on CephSmile V2 Executable Shown by Dede

Figure 13. Obfuscation Results on CephSmile V2 Executable Shown by IDA Pro Interactive Disassembler
5. Discussion and Conclusion

The results of the CephSmile V2 Program, database system and CephSmile Plus Services, have demonstrated that the system under discussion can perform Software Plus Services. With CephSmile Plus Services, the pre-paid user access account can be set up in four different packages. The details are given below:

- **Silver package**: It provides time-based user access controls with a limited number of hours the user is allowed to operate the program. All timing is measured in seconds, which provides great flexibility.
- **Gold Package**: It provides a number of usage-based user access controls with a limited number of usages that the user is allowed to operate the program, with an additional two-hour limit for each time usage.
- **Platinum Package**: It provides duration-based user access control with date and time set up to start and end for using the program.
- **Titanium Package**: It provides group-based user access control with limited IP address and username/password required for using the program. It is appropriate for a university or hospital requiring frequent use of the program.

The packages have also been divided into three packs with different amounts of functions available along with the preset expiration dates that become effective after a given number of days. The conclusion is that CephSmile Plus Services can be provided to the orthodontist community as software plus services.

6. Acknowledgement

We appreciate the contributions from the orthodontist team from the Department of Orthodontics, Faculty of Dentistry, Mahidol University for studying the accuracy and precision of the CephSmile V2 Program along with special thanks to IMS, Medical Cluster, National Electronics and Computer Technology Center (NECTEC), and NSTDA for grant support.

7. References


[24] Travel Web Max “Encode or Decode MD4, URL encoding, Base85 (ascii85) and Base64”, available online at http://tools.web-max.ca/encode_decode.php


