Development and Validation of Strategies to Test for Interoperability of Virtual Patients

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Abstract. Interoperability of e-learning resources requires the adherence to specific standards. In the domain of virtual patients (VP) a central role is played by the MedBiquitous' MVP specification and its application profile proposed by the eViP (Electronic Virtual Patients) project. An important factor in promoting a standard is the use of metrics for assessing the conformity of the resources to the constraints imposed by the specifications. The overall aim of this study was to explore strategies to test for conformance and investigate the capabilities and limitations of automated conformance testing. A four-level scale of conformance of virtual patient packages to the eViP profile is presented, as well as two implementations of conformance testing applications. The developed tools have been tested upon level two on a sample of four VP cases acquired from the eViP repository of virtual patients.

Keywords. standardization, virtual patients, simulation, conformance

1. Introduction

Interoperability standards are an important area of research in the medical educational informatics domain: by exchanging sharable content objects we hope to accelerate and enrich the process of developing computer-aided learning activities. In the field of medical e-learning an important role is played by the ANSI-accredited MedBiquitous consortium which drives an international effort towards standardization of educational content in medicine and healthcare [1]. One of their emerging standards is the Virtual Patient Specification (MVP) [2]. Virtual patients (VP) are interactive computer simulations of real-life clinical scenarios created for the purpose of medical training, education, or assessment [3].

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In practice it is not always feasible to implement whole specifications. For that reason application profiles are created which optimise one or more specifications for the purpose of a given application. To meet the special needs of partner institutions in the European project eViP [4], whose aim was to share VPs in a common database [5], a derivative of this MVP specification was created: the eViP application profile, which differs from MVP mostly in metadata (using IEEE 1484.1.2.1 LOM). eViP conformant virtual patients are SCORM packages containing files that describe different aspects of the VP model: clinical and narrative data, activity and data availability models. The eViP profile has already been implemented by four VP systems [6].

Substantial research has been done in the field of conformance testing of software systems so far. Various evaluation methods for adherence of candidate implementations to standards have been proposed in such disciplines as real-time communication [7], distributed artificial intelligence [8], B2B applications [9], hospital information systems [10] and many more. This paper concentrates on the content-level conformance testing [9] in the area of specialized reusable learning objects – i.e., virtual patients. Until now, little research has been conducted into the process of testing conformance with VP specifications. In addition, there were no applications available that enable the community to automate conformance testing. This paper focuses on these two aspects of sharing VPs.

2. Material and Methods

2.1. Levels of Conformance

In order to be successfully imported into an eViP profile-compliant system, a packaged VP needs to conform to the eViP application profile. The process of conformance testing can be described in four nested levels of increasing complexity. Ideally, a packaged VP should fulfil all four levels. However, in the eViP project, compliance to third level was set as the highest goal, technically achievable within the project's scope. Below we describe the different validation levels on which the development of the conformance testing tools is based on.

The first and lowest level of conformance implies that the archive structure and overall content is conformant to the eViP profile specifications. This means that the directory structure and file names are correct and that all required files are included. The content of files is ignored at this stage. This validation is straightforward to automate, and the conformance checking tools that have been developed provide this functionality.

The second level of conformance requires that the XML files are well-formed and valid according to their schemas. Internal and external references in files from the package, references to media resources, and references within the content of the metadata file are checked. No check is made for the presence of spurious, non-referenced items in the package, as this is outside the scope of this level of validation. Level 2 conformance validation can also be easily automated and has been implemented in two eViP conformance test suites.

The third level of conformance is less straightforward to define: the package must be imported by an eViP-compliant system in a meaningful way. It is best described by a set of requirements:

- The key requirement is that an author obtains a clear benefit from importing the package into the system in comparison with copying the content manually.
- After import, enough data must be available to enable the author to start working on the case in the new system.
- The main sections of the VP package are recognized by the target VP system – i.e., there is a clear separation between narrative/clinical data describing the case and data defining the activity and data availability model.
- The package should not contain non-referenced items.

Optionally, selected fragments from the package can be imported automatically into the target proprietary VP model. The import process may be customized and controlled by the user, allowing a conversion between different system models. Manual extensions are usually required to make the case logically consistent.

The fourth level is the most demanding level of conformance. It states that the imported VP must run in an eViP-compliant system corresponding to the way it is presented in the original VP. Again a set of desiderata is the best way to define this level of conformance:

- No case-related data is lost while importing the package
- The way the data is displayed, reflects the main path as it was presented in the original system. The storyline of the case remains consistent.
- The educational value is retained.
- The learning objectives planned for the case in the original system are also achievable in the target system.

As with level 3, conformance to level 4 is as much a property of packaged VPs as it is of eViP-compliant systems. Moreover, a highly subjective aspect is added that has to be judged by content or didactical experts. Level 4 conformance will only be defined relative to the source and target system: an exported VP package could be level-four compliant for import in one platform, but not for import in the second system.

2.2. Development of the Applications

The first two conformance levels of the eViP profile can be automatically checked by ancillary software, whereas the last two, due to their semantic aspects, involve human intervention. This section focuses on the first two levels. Where possible, suitable validation software was selected from a list of pre-existing tools. New modules were developed in those cases where no appropriate component was available. Validation against level 1 requires a simple check for the presence of a set of files prescribed by the eViP profile. From the technical point of view this task does not create any difficulties. The validation tool needs to unzip the package and compare its content with the correct list of files. However, because the eViP profile is based on newly developed specifications, it was necessary to implement this feature anew. The second level of conformance examines the common problem of well-formedness and validity of XML files. For that reason its solution required only the selection of a suitable tool from a long list of publicly available software. JAXP and Xerces libraries were used for the purpose of determining local schema-validity in the eViP profile. Conformance validation tools for this level need to verify the correctness of the references in an MVP package (either Xpath expressions or identifier attributes). This includes verification of the existence of referenced elements and the detection of unused resources. Such functionality was not present in the available software and had to be developed by the

eViP consortium. Rather than using each module from the set of validation tools separately, it was decided to develop a single application – an eViP conformance testing suite – that merges all tools for handling the whole validation process. Two concurrent solutions emerged representing different implementation approaches. The conformance testing suite developed by Karolinska Institutet uses in their analysis a Java implementation of the Document Object Model (DOM) interface, whereas Heidelberg developed a suite based on XSLT templates.

2.3. Case Study

The conformance of four VP cases from the eViP repository has been tested. Table 1 presents the list of VP packages tested for eViP conformance.

Table 1. Set of VP packages tested for conformance

ID	VP System	VP Model	Topic
#1	CAMPUS (Key Feature): Heidelberg University	Terminology-based	Bacterial meningitis
#2	CASUS: Ludwig-Maximilian-University	Linear	Chest radiography
#3	Open Labyrinth: St. George's University	Branched	Malaria
#4	Web-SP Karolinska Institutet	Semi-linear	Pneumonia

The chosen set of cases represents a full spectrum of different VP models and systems of the eViP project. In addition, variants of cases have been created and tested by changing export options (e.g., including QTI (IMS Question & Test Interoperability) questions – case #2, and local extensions of the eViP profile – case #1 and #4).

3. Results

3.1. Conformance Testing Applications

Heidelberg University (HD) has developed an XSLT conformance suite that is a simple, yet powerful and easy to extend tool for testing of all kinds. The XSLT conformance application mostly uses plain W3C standard XSLT to develop tests (currently there are 20) for many areas including file validation (missing files), reference validation and schema validation for all schema included in the eViP profile. The suite can also detect unreferenced elements, check for meaningless attributes, find duplicate IDs and identify any media references made using non-recommended methods. The suite produces results either in XML (for integrating into applications) or an HTML format (for easier reading). The suite can be run as a standalone application (JRE 1.6+ required) or as a web service (for a Servlet container such as Apache Tomcat). The suite is open source[2] (LGPL).

The eViP Conformance testing application developed by Karolinska Institutet (KI) is an open source[3] web-based application written in Java. The primary aim of the application is to help implementers to verify that a VP package is compliant with conformance levels 1 and 2 of the eViP profile. As the MVP specification evolves, the application will need to be updated to test for the latest version. Since the source code is available, future efforts and improvements may be conducted by a wider community

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[2] http://code.google.com/p/mvp-evip-xslt-test-suite.
[3] http://code.google.com/p/mvptools.

of developers. The reporting section of the application could be extended to further assist the testers and parts of conformance level 3 could be supported by the tool.

3.2. Case Study

The eViP testing suites have confirmed that all four test cases are level 1 and level 2 conformant with the eViP application profile 2.0.1. In addition, by importing cases into eViP partner VP systems most have been proven to be 3rd level conformant. It is worth noting that even the transfer regarded by many as the most difficult – i.e., from branched into (semi-)linear models – has been achieved at conformance level 3. Among the most common problems observed in the course of the validation process were: conformance to outdated XML schemas, duplicate identifiers and references to non-existent elements. In most instances imported VPs required manual post-processing operations. This fact clearly indicates that conformance level 4 between VP systems has not yet been reached.

4. Discussion and Conclusions

This paper presents a strategy for testing conformance of VPs to the eViP application profile of the emerging MVP standard. The validation is performed on four successive levels. The testing of the first two levels was automated by two conformance suites developed by some of the authors. The remaining two levels could not be realized without human intervention, due to a high semantic level involving such terms as meaningfulness and usability. However, the future work of the authors will focus on the further development of the conformance tools to better assist the human reviewers in evaluating the import of cases on higher conformance levels.

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