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Enhanced IMS Metadata for Surgical Education Simulators

Nergiz Ercil ÇAĞILTAY*
İbrahim CERECİ**

ABSTRACT

Surgical education is an important field in medicine that is directly related with human health. Generally, this education is a time consuming and difficult process. Since surgeons will perform a job that significantly effects human life and quality of living with no room for error, the mentioned education has dramatic impact on patients, on their relatives, and also on society. In the literature, studies show that simulation environments potentially support and enrich this education. However, studies also show that even the several successful simulation tools being developed for the surgical education, still the integration of these technologies into the curriculum of education programs is not successfully established. This study proposes an enhanced IMS Metadata for surgical education simulation content. The proposed model is expected to help the surgical educators to better sequence this content in their curriculum and to better structure their courses. The authors believe that, by supporting these standards the simulation content developed for surgical education could be better defined by technically and pedagogically and in turn the success rate of the integration process of these technologies into current education programs will be improved.

Keywords: medical education, simulation system, surgical educatio, meta-data, extensible markup language

1. Introduction

Surgical education requires very important knowledge and skills to be gained. Studies report that, lethal errors (Gordon et al, 2001) can be faced when skills are not trained properly and need to be put in practice suddenly (Berkenstadt et al, 2003). Traditional medical education for hundreds of years has been based on “learning by doing” type of methods (Karaliotas, 2011). For centuries, surgeons have performed the operation by directly viewing and feeling the internal organs and reaching diseased organs. On the other hand, the introduction of the microscope and later the extensive use of the video camera have changed the way of operations

* PhD, Assistant Professor, Atılım University, Software Engineering Department.
** Lecturer, Atılım University, Computer Engineering Department, icereci@atilim.edu.tr.

which have replaced the direct vision by a video image. These types of surgical techniques are generally called as minimal invasive surgery (MIS). Laparoscopic surgery and endoscopic surgery fall in this category. Minimal Invasive techniques are rapidly becoming a standard surgical technique for many surgical procedures (Schreuder et al., 2011).

Most of the traditional surgical training takes place in the operating theater under supervision of an experienced surgeon and based on the "see one- do one-teach one" method (Silvennoinen, 2009). This method does not allow any try-and-error type of learning. Hence the learning process does not tolerate errors. This situation makes the education process more complicated and requires longer time-periods. The learners as well as the educators face several problems during this process (Dietze et al., 2014). In order to address these problems alternative learning environments have been researched. One of these alternatives is using animals for educational purposes in the operating theater. Since anatomy of animals sometimes varies greatly from that of humans (Karaliotas, 2011), it is not always a preferred educational environment. Additionally, surgical procedure on animals offers just one time experience and cost much. It also raises some ethical issues (Karaliotas, 2011). Other educational approaches are the human cadavers, animal models and box trainers (Andersson, 2007). Since human cadavers provide just one-time experience, it is expensive and the dead tissue does not always provide a real experience (Karaliotas, 2011).

In addition to these, it is also not appropriate by the ethical reasons to train the basic concepts on living human patients, the requirements of higher challenging and complex surgical problems cannot be appropriately taught in such environments and finally, there are still some skills need to be taught to a novice surgeon prior to clinical applications (Grober, 2004). However, there are several factors showing that the operating theater is not the ideal education environment for the novice surgeon (Grober, 2004). Work-hour limitations, faculty time constraints and increased operating room costs are main limitations for providing training in operating theater (Santry & James, 1998). Accordingly, it is not very convenient for the efficient use of operating theater.

Since the mid-1980's several attempts has been conducted to improve surgical education. The earliest studies in this scope are the video assisted methods used for endoscopic surgery (Silvennoinen et al., 2009). Since then, several versions of surgical simulators have been developed (Rudman et al., 1998; Robb, Aharon & Cameron, 1997). Virtual reality surgical simulators have begun to be used in training in late 1980's partly as a result of these developments (Silvennoinen et al., 2009).

Virtual Reality (VR) simulators have been developed as an alternative method for the previous trainers. In virtual reality based surgical simulation, all the elements such as tools, organs, bones, tissue and anatomical model related to the operation are computer generated. User does the operation in this virtual environment and the environment is expected to behave like the real one. Those systems usually have an objective assessment of performance but they lack of realistic feedback. MIS is by nature very suitable for virtual Reality type of trainers (Schreuder et al., 2011). The specific psychomotor skills and eye-hand coordination needed for MIS can be mastered largely using VR simulation techniques (Schreuder et al., 2011). It is also possible to transfer skills learned on a simulator to real operations, resulting in error reduction and shortening procedural operating time (Schreuder et al., 2011). Models of virtual patient can provide an evolved realistic human anatomy, simulating normal and pathological conditions in a virtual reality environment (Karaliotas, 2011). In addition, simulators can provide a structured learning environment with controlled levels of difficulty (Karaliotas, 2011). Since task based evaluation can be automated in virtual reality simulators, trainee can be given feedback during the training session, and training can be customized for the needs of the user. Hence, the surgical simulation environments are important technologies to improve traditional education in surgery. On the other hand, in order to improve possible benefits of these environments for the classical education and better integrate these tools into the current education environments, the specific features of surgical simulation environments need to be understood and documented well. In the following session main features of these tools are summarized.

2. Main Features of Surgical Simulation Tools

Goals and Objectives: The goals and objectives are one of the main educational features for a specific learning content and according to the learning needs of the educational program. The goals and objectives of the educational program should match with the supported educational content. For an easy and successful integration of educational technologies to the current educational environments, educators need to define their specific educational goals and objectives in an appropriate way, not too general, in a measurable manner, appropriate with the learners' levels and, requirements and learning needs of the educational program. McGaghie et al. (2011) also report that well defined learning objectives are one of the important factors for a deliberate practice. Based on these requirements they also need to easily search for appropriate supporting educational materials addressing their educational problems and enriching their teaching. DaRosa et al. (2011) define the goals and objectives and the learning needs as curricular barriers on effective teaching in medicine.

Curriculum Sequencing: Curriculum sequencing is another important issue for designing a successful curriculum. According to DaRosa et al. (2011), the unstructured sequencing of clinical experiences inherent in clinical education makes for chaotic and inconsistent learning. The sequence of the content provided to the learners usually guide them to learn complex situations in a stepwise approach and helps to provide appropriate feedback to continue with the higher levels of the content. Hence the level of experience of learners shall be closely correlated with the curriculum sequence of the educational content. In other words the content should be provided in an appropriate level of difficult with the learners' experience and knowledge levels. McGaghie et al. (2011) also report the importance of appropriate level of difficulty for a deliberate practice.

Reliable Measures: Assessment and measurement is one of the main areas in education. Without measuring and assessing the success of the education programs, the progress of the learners and, the level of achievement to the learning outcomes cannot be understood. Hence rigorous and reliable measurements shall be provided in a deliberate practice (McGaghie et al. 2011).

Feedback: Based on the assessment results through the learners' work in an educational program, the informative feedback from educational sources (e.g., simulators, teachers) shall be promoted (McGaghie et al. 2011). This feedback information would guide both the educators and the learners to design the next levels of the educational programs. Andersen (2012) report that immediate evaluation and feedback inform improved performance and can help to design more challenging scenarios based on trainee's demonstrated skills.

In the literature there is no guidance or classification model to help the surgical educators to better address these technologies and understand potential impact of them. In the literature there is a metadata specification for learning resources (IMS, 2014) however this definitions are too general and do not include specific requirements for the surgical education simulators. In this study such a classification model is proposed. Accordingly, the proposed extensions can be adapted to this system to address specific requirements in this domain.

3. Metadata Standards for Learning Resources

Today, the main problem for improving current educational systems is the technology integration. Although there are available technologies to address some problems of conventional educational environments, it is not always possible to integrate those technologies in a classical education curriculum. To help educators to better integrate the advanced technologies into their own curriculum one should provide detailed information about the features of the technological tool. This will help the educators to compare similar materials and decide in which sequence and structure the educational material should be integrated in to their educational curriculum. IMS learning resource metadata specification (IMS, 2014) provides a good standard approach for these purposes. This standard provides some elements such as general (general information that describes the learning object as a whole), lifecycle (features related to the history and current state of the learning object and those who have affected this learning object during its evolution), metametadata (groups information about the meta-data instance itself), technical (groups the technical requirements and characteristics of the learning object), educational (educational elements describing the use of the resource), rights (conditions of use of the resource), relation (features of the resource in relationship to other learning objects), annotation (comments on the educational use of the material) and classification (description of a characteristic of the resource by entries in classifications) (IMS, 2014). Researchers state that this standard is lacking in the areas of pedagogy, adaptive learning and learning assessment data (Chang et al., 2004; Mustaro & Silveira, 2007; Huang et al., 2006). Hence according to them it can be extended by the three approaches of adding new metadata elements, adding new vocabulary for metadata elements, and references to an internal or external XML file using the location element (Mason & Ellis, 2009). Since these standards are developed for general purposes for all learning materials, it is a complex procedure for the surgical educators to adapt this system into their instructional materials. Secondly, this system does not include features for the assessment purpose (Chang et al., 2004) and specific features for the surgical education simulators. The enhanced assessment model of the SCORM (Chang et al., 2004) is also addresses knowledge level of assessment. However, for the surgical education simulators, the skill level assessment features are very important. Hence an enhanced model of these standards is required to be adapted to the field of surgical education simulators. The main aim for this enhancement should be the adaptation of the learning material into the medical education curriculum.

4. Proposed Classification Model (ECE)

The ECE model is proposed to classify the surgical education simulators, according to their technical and educational features to help the educators to better integrate these tools into their curriculum and to better address the required technologies for their teaching. Additionally, a proposed xml structure for this classification will provide a standardized coding schema for this classification. The ECE model classifies the features being supported by the simulators and provides a scale to rate their level of support. This version of the proposed elements is named as version 1.0.

<?xml version=”1.0” encoding=”ECE-1001-1”?>

The proposed elements for the surgical education simulators are described below.

5. Haptic Interface

One of the important features for these systems is the haptic interface (Cereci, Cagiltay & Berker, 2013). The simulators vary according to the level of support on these haptic interfaces. Hence the first classification of the ECE is on the haptic interface. The haptic interface support is classified into two levels. The first level shows the number of haptic devices being supported at the same time. The second level shows the level of feedback supported by these haptic devices. The supported feedback is related with the force-feedback as well as the level of supported degree of freedom (DoF). This tag can be adapted to IMS structure under "2.6 <educational> <interactivitytype>" definition (IMS, 2014).

<hapticinterface>

<name>

"name of the haptic device for example endoscope for surgent, endoscope for assistant etc"

</name>

<feedback> "0:no feedback,

1: Vibration,

2: Classical DoF,

3: Higher DoF"

</feedback>

<description>

"description how the haptic device functionally used in the simulation"

</description>

</hapticinterface>

<hapticinterface>

<name> </name>

<feedback> </feedback>

<description> </description>

</hapticinterface>

For each haptic interface defined in the simulator, this definition need to be given. In other words, each <hapticinterface> tag defines how each haptic device is used in the simulator. In the example below the haptic simulates the endoscope however no feedback is provided in the practice provided in this scenario.

```
<hapticinterface>
        <name>endoscope</name>
        <feedback>0</feedback>
        <description> endocope practice </description>
</hapticinterface>
```

6. Model

The second classification is on the model being used in the simulation system. The level of the model represents how the model being used in the simulation system is developed. Some simulation systems do not use a medical model. Generally some educational scenarios to provide necessary basic skills have been implemented on these systems (General). Some simulators are using an anatomical model that is developed by a designer. These models do not use medical data for digital transformation processes (Designed). On the other hand, some simulators are based on anatomic models that are transformed from medical data of the patients. For example these models are developed by using engineering techniques applied to MRI and CT of a patient (Transformed from medical data). The Model classification can be enriched according to the future technologies. This tag can be adapted to IMS structure under “2.6 <educational>” definition (IMS, 2014).

```
<model>
        <name> </name>
        <feedback>  ”0:no feedback,
                     1: Vibration,
                     2: Classical DoF,
                     3: Higher DoF”
        </feedback>
        <description> </description>
        <level>
                     ”1:General,
                      2:Designed,
                      3:Transformed from medical data”
```

</level>

</model>

7. Surgical Skill Level

The surgical skill levels are defined in five levels (Silvennoinen, 2009). According to this definition, the beginners have merely non-specialist knowledge of a domain, the novices have begun to develop the elementary knowledge assumed in the domain, the intermediates have already deepened their knowledge above the beginner level, subexperts are medical specialists capable of solving problems outside their domain of expertise and the experts having specialized knowledge of the subdomain (Silvennoinen, 2009).

<surgicalskilllevel>

"1: Beginner,

2: Novice,

3: Intermediate,

4: Subexpert,

5: Expert"

</surgicalskilllevel>

This tag can be adapted to IMS structure under "2.6 <educational>" definition (IMS, 2014).

8. Assessment Feedback for Educator

Usually the assessment data is collected through the performance of the user during the usage of the simulator. This data contains detailed information about the system usage such as durations, reputations, successful or unsuccessful attempts, strategies, etc. The feedback system presented through analyzing this data is very helpful for both the educators and the learners. The assessment feedback guides the educators about the performance of the learners on the simulation system. This feedback is also important to help the educators to better manage the educational program through the simulation system. The simulation systems sometimes do not provide any feedback. Some simulation systems provide general percentages and descriptions about the users' performance without using any systematical analysis. This type of feedback level is considered as "General" in the ECE system. This type of analysis do not provide details about each skill level to be gained instate provides a general information about the users' progress in general. The feedback system that reports the user performance on the system by applying some statistical or other analytical approaches in a descriptive way is considered as "Detailed" feedback. This type of feedback also provides detailed information about each skill level to be gained. Above those, if a dimensional model is implemented on top of this data by considering medical intelligence approaches and analysis, the feedback level is coded as "Medical intelligence" level. Hence, the <assessmentfeedbackeducator> tag represents which level the assessment feedback for the educators is provided in the simulation system. This tag can be adapted to IMS structure under "2.6 <educational>" definition (IMS, 2014).

<assessmentfeedbackeducator>

"0: None,

1: General,

2: Detailed,

3: Medical Intelligence,

</assessmentfeedbackeducator>

9. Assessment Feedback for Learner

The <assessmentfeedbacklearner> tag represents which level the assessment feedback for the learners is provided in the simulation system. The same approach for the educator feedback levels are used in this classification as well. The assessment feedback guides the learners about their performance on the simulation system. This feedback is also important to create a self guided educational environment.

10. Curriculum Integration

The level of support for the curriculum integration is an important classification factor for the surgical education simulators. This factor evaluates the flexibility of the system for adapting it to the curriculum of the classical education. This tag can be adapted to IMS structure under "2.6 <educational>" definition (IMS, 2014).

<curriculumintegration>

<standalone> "Yes, No" </standalone>

<adaptation> "<number of parameters>" </adaptation>

</curriculumintegration>

Educators may adapt the same simulation system according to the level of learning progress of the learners. This adaptability feature is very important for the educators to integrate the simulation systems into their environments and educational requirements. In this feature, by defining some standard levels for the adaptation abilities of the simulation systems, this element can also be defined under some level definitions.

11. Discussions and Conclusions

Although several improvements have been achieved in the field of surgical simulations to improve the traditional training and education in this field, they all have some beneficial opportunities coming with their own limitations. The studies found in this area show that there is a continuous development for generating different instructional alternatives for the surgical education. The latest technologies used in this field mostly use the virtual reality and augmented reality techniques.

The studies found in the literature in this field show that for the development of a real-time simulation systems, the current performance of computers are very limited for generating realistic simulations. Hence the development of new algorithms and methods is still mandatory (Cotin, Delingette & Ayache, 2000). In Turkey we could not reach any educational environments using these new technologies such as virtual or augmented reality simulators for the MIS education. In the world there is very limited number of medical schools providing these type of technology integrated instructional environments. Main reason for this limited usage of these technologies may be the limited availability of these technologies specific to the field of the surgical education requirements. In order to make a significant improvement in these educational environments an integration model for this technology to the traditional educational environments is required. Additionally more specific tools for specific surgical operations need to be developed.

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