Title: Data management workflow and architecture for simulation-based medical training

Background

Computer assisted simulation-based medical training and skill assessment has been receiving steadily growing attention during the past decade. Typically, systems compute and record a variety of performance metrics in order to assess trainee skill and competency. Numerous studies emphasized the importance of quantitative trainee feedback for effective simulation-based medical education. Over the years, significant research has been conducted into various quantitative metrics for determining competence, how many times a given skill must be practiced to achieve and retain competence, and how competency on simulators translates into operating room ability [1].

This type of research requires a significant amount of data recording and data mining. For example, in a typical exploratory study [2], the researchers tracked and recorded 6 different metrics, for 40 subjects, each of whom carried out 8 different procedures, thus adding up to almost 2,000 data points. In addition, pre-testing for baseline values and post-testing for retention further multiplied the amount of data.

Extensive literature review showed that studies focus on publishing results with virtually no mention of the methodology and software used for recording and managing study data. This practice is highly problematic for multiple reasons. Firstly, without documented data recording and management methodology, it becomes all but impossible to reproduce their results. Secondly, the complexity of managing large volumes of data encourages researchers reduce sample sizes to simplify data collection, thus making it difficult to draw conclusive statements. Thirdly, without suitable alternative, the majority of researchers rely on entering data manually into simple spreadsheets - a method that is both time-consuming and error-prone. Finally, lack of study data management facilities prevent rolling out simulation-based training methods into institution-wide curricula with self-guided training and testing. Throughout our investigations, we were not able to find any open-source tool for managing data associated with simulation-based education programs.

Objective

Hence the overarching objective of this project is to develop a practical data management workflow and architecture for simulation-based medical training and implement these as freely available open-source resources for researchers and commercial entities alike.

Methods

In order to determine key requirements, we consulted medical training experts who routinely use the Perk Tutor for trainee evaluation. With this information, we documented the current workflow and identified its limitations. A data flow diagram was used to represent the workflow.

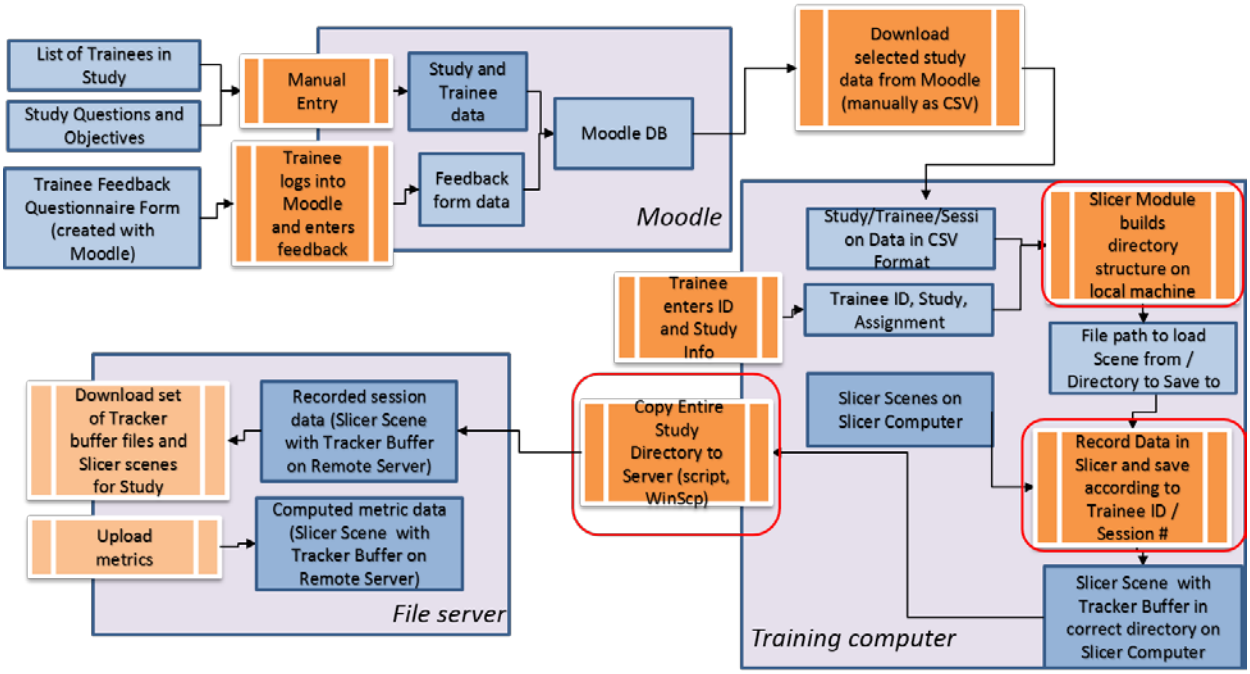
We designed the required data management to be compatible with the Perk Tutor (www.PerkTutor.org) free open-source medical simulation platform, developed primarily for image-guided intervention training [3]. Perk Tutor is based the 3D Slicer (www.slicer.org) and Public Library for Ultrasound Research (www.plustoolkit.org) open-source platforms [4]. In Perk Tutor, a number of simulation-based training systems have been implemented as 3D Slicer plugins. This prompted us to package our data management facilities, combined with data analysis modules in the Perk Tutor extension, thus yielding a complete open-source simulation training facility that is conveniently available through the 3D Slicer extension manager.

One of the key required features was the calculation of a set of metrics for determining a medical trainee's proficiency in image-guided minimally invasive interventions. As is the case with other simulation software, it was missing a tool for collecting and organizing the data generated for offline analysis.

In the analysis phase of the project, an objective comparison of storage options was conducted by ranking each of the options on a scale of 1 to 5 in terms of how well each one satisfies the given criteria. The options considered were: XML-based storage, CSV files, Moodle (an e-learning platform) and two database tools (SQLite and MySQL). The primary outcomes of this project is the design and implementation of a software extension for Perk Tutor simulation training.

Results

The Moodle open-source learning management system (www.moodle.org) was found to be the optimal storage solution based on its built-in authentication and web interface for viewing and editing data. Moodle is extensively used by universities for managing courses, assignments and exams, including confidential materials, in a manner that provides two-way protection against tempering by trainees and unauthorized persons. The resulting workflow consists of the following steps. First, the Perk Tutor module downloads and parses data in CSV format from Moodle. Second, simulation data is recorded and automatically saved to the correct directory based on session metadata. Finally, the saved data and metadata are uploaded to a password-protected file server and Moodle, respectively and may later be downloaded for analysis. The Figure below captures the data flow diagram and outlines in detail the resulting workflow design. Unfortunately, due to space constraints, we cannot discuss the figure in detail.



This data flow diagram was used in the implementation of the software extension. The result was the implementation of a software extension for acquiring relevant metadata and ensuring that the simulation results are securely stored and accessible for analysis, implemented as designed within the Perk Tutor platform.

Conclusion:

The new workflow design allowed us to implement a software module within the open-source Perk Tutor image-guided intervention training platform. Following full testing currently underway, the complete system will be released as open-source through Perk Tutor distribution site (www.PerkTutor.org). Future work includes surveying users to evaluate the usefulness and performance of our data management solution.

References

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