The LiverAnatomyExplorer: Design and Evaluation of a WebGL-based Surgical Teaching Tool

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Purpose

Against traditional medical teaching, web-based medical learning tools offer a number of advantages, like time- and distance-independent learning [1]. There exist a few online medical learning platforms, e. g., S*urgyTech*, *BioDigital Systems or Zygote Body*. But the majority of these online platforms only provide movies of surgical interventions or they are often limited to a small number of cases. The anatomical situs is often reconstructed using 3D-modeling tools [2]. Real patient-specific anatomical and pathological conditions and self-assessment tools that provide immediate feedback to the learner are largely missing. In this article, we describe the development of a web-based medical learning tool: the *LiverAnatomyExplorer*. The system provides clinical 2D image data as well as interactive polygonal 3D models. In close collaboration with medical experts at the *Asklepios Clinic Barmbek, Hamburg, Germany,* we selected appropriate patient cases with liver tumors, metastases and vessel anomalies. We provide an integrated training package that includes diagnosis and surgical reports, clinical image data with colored overlays, easy-to-use interactive 3D models, surgical video clips and self-assessment exercises.

Methods

We started with a detailed requirements analysis with potential end users: 176 medical students and 19 clinicians filled an online questionnaire. It turned out that many students would benefit from clinical case collections with medical imagery and 3D representations of anatomical basics. Most of the clinical subjects (76 %, 10/13) are interested in providing interactive 3D graphics, clinical imagery and movies as complementary learning materials for trainees. The analysis also showed that 97 % (171/176) of the students and 54 % (7/13) of the medical experts never or rarely used 3D visualizations so far. We used *MeVisLab* to process and convert 13 real clinical cases. After identifying and segmenting the important structures, they need to be exported in a web-compatible format. In our case, the segmentations of liver, tumors and vascular structures have been performed by medical experts with deep anatomical knowledge at *MeVis Distant Services, Bremen, Germany*. In order to achieve a fast online access of anonymized patient data, we chose JPG as export image format. The resulting segmented areas are automatically exported as SVG files. For web-based rendering of 3D models, the size of the meshes is more crucial than for local use. The simplified surface mesh has an overall size of about 5-10 MB (ca. 100.000 polygons), which enables fast web-based rendering. The surface mesh is exported as a single X3D file. We use X3D, an ISO Web3D standard, since X3D files can be easily integrated and rendered in real-time, without any plugin, using WebGL and X3DOM [3]. The exported clinical 2D data and segmented areas are presented in our combined 2D/3D viewer based on HTML, SVG, JavaScript and WebGL (Fig. 1, left/right). The WebGL-rendered 3D scene can be rotated, panned and zoomed freely in the 3D viewer. Immediate customized feedback mechanisms are essential for students to gain knowledge and to monitor individual learning curves [4]. Therefore, we have integrated a multifunctional self-assessment tool. Beside typical textual multiple choice questions, we enhance the quiz to interactive 2D and 3D click answer options. High-quality surgical images or movies composed and annotated by an expert surgeon, can be used by the learner as additional learning material.

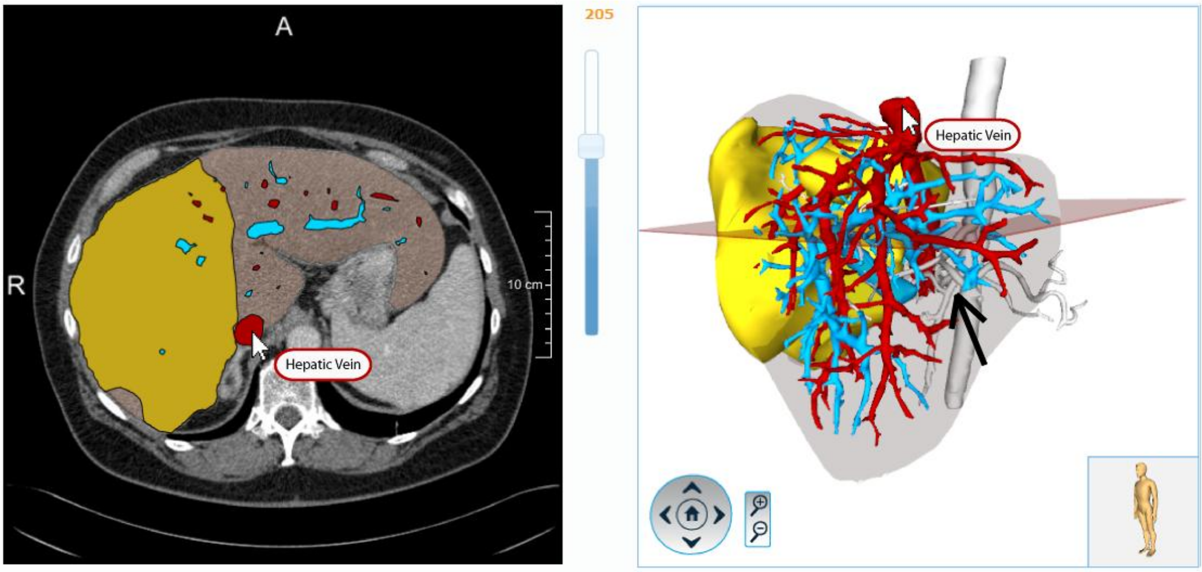

Fig. 1. Synchronized 2D/3D viewer. Left: Interactive web-based 2D viewer with radiological CT slices and colored SVG objects indicating important anatomical and pathological structures. Right: Interactive WebGL 3D viewer. A 3D widget (bottom left) can be used to easily rotate and zoom the 3D model. The black arrow points to a clinical important vascular variant, an accessory right liver artery.

Results

We conducted an evaluation with 54 medical students (average age: 24, gender: 40 f / 14 m, 7^{th} to 9^{th} semester) to investigate the user experience and learning aspects of the *LiverAnatomyExplorer*. After testing the web application, the subjects were asked to fill an online questionnaire (statements are scaled using a five-point likert scale (1= “Strongly disagree” to 5=”Strongly agree”). The analysis of the user study showed that the website has a modern and attractive design (average of 3.94) and the navigation is self-explanatory (average of 4.22). The orientation guides in the 3D viewer and the tutorial were highlighted by many subjects to be very helpful. The learning aspects of the *LiverAnatomyExplorer* were also rated “good”, with some exceptions. On the one hand, the subjects highly rated the reality of the learning contents (average of 3.98) and the knowledge gain due to the multi-modal, individual liver anatomy data (average of 3.96). On the other hand, it turned out that the questions concerning liver segments and vessel anomalies are too specialized for medical students at this education level.

Conclusion

Our architecture could be easily adapted to other organs, since we use X3D as free ISO exchange file format and WebGL as heterogeneous free rendering engine. Further interviews with medical experts are necessary to tailor the learning contents to the user needs. To avoid social isolation of learners, online discussion groups and feedback mechanisms have to be provided to allow student-tutor communication [4]. Currently, we are working on a web 2.0 surgical collaboration platform. The goals of the platform are: enabling access to user-generated teaching materials, sharing medical knowledge, and the collaborative discussion of novel surgical techniques/equipment between experts, assistants and students.

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