An Authoring Interface for Surgeon-Authored VR Training

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1 Purpose

Virtual reality (VR) simulators allow trainees to practice decision-making and execution prior to entering the OR. VR-based training can thereby increase patient safety, reduce the need for in vivo animal practice, shorten time in the OR, and provide the repetition and learner control [4]. VR-training can also uncouple instruction place and time to address limitations placed by work-hour rules and real-life scheduling of surgeons, residents or medical and veterinary students.

Laparoscopic techniques, in particular, lend themselves to VR simulation due to their interface: tissue is manipulated only via tools and the surgical environment is visible only via a camera image on a monitor. Haptic devices resisting probing, tearing and cutting, provide the necessary force feedback for hands-on, interactive simulation of the critical steps of the laparoscopic procedure [5].

However, creating VR-training units is neither cheap nor fast due to the complexity of creating the training units and the back-and-forth between engineers, computer scientists and medical experts. Inspired by the success of many computer-tools, such as desktop publishing, a Toolkit for Illustrations of Procedures in Surgery (TIPS) [7] has recently been developed to more efficiently generate touch-enabled VR-training simulations. Specifically, the goal is to enable surgeon-educators to define the structure of training units.

Enabling surgeon-educators to create VR-training units promises greater variety, specialization and relevance of the units. It allows implementing variation in technique, an important component of traditional surgical education, and to create uncommon and specialized scenarios.

We report on a web-based authoring interface that allows surgeon-educators to assemble simulation-ready pieces of VR anatomy and tools to quickly specify new surgical scenarios. This interface has successfully been used by surgeon-educators to create laparoscopic training units for appendectomy, cholecystectomy and adrenalectomy.

2 Methods and Materials

The authoring interface is part of TIPS, a low-cost computer-based environment to create touch-enabled VR laparoscopic simulation scenarios. TIPS is based on C++ and OpenGL, runs on a high-end PC or laptop. Two touch styluses, attached to surgical tools, provide the interactive force-feedback required to practice critical steps of the surgical procedure. Over the past two years, 23 junior surgeons (residents and fellows) and five experienced surgeons trained and graded an adrenalectomy unit created with TIPS and judged it both effective and superior to physical props, one-on-one teaching, medical atlases, or video recordings [6].

TIPS leverages and integrates two open-source packages: Blender for modeling anatomy and the Simulation Open Framework Architecture (SOFA) for soft-tissue simulation. Blender [2] is a professional open-source geometric modeling, rendering and animation software. Several animated movie shorts have been created using Blender as the main modeling and rendering environment. SOFA [1] is an open-source collection of numerical, geometric and visual routines for developing simulation codes with focus on soft-tissue manipulation. TIPS' Blender2Sofa software links the two packages and augments the Blender graphical user interface with control of physical behavior, attachment and collision properties. A single click starts the full force-feedback enabled anatomical scenario assembled in the augmented Blender environment.

When a scenario is judged to be complete and correct by peer review, a command in Blender2Sofa breaks the scenario apart into simlets. Simlets package compatible geometry, collision and physics models with their default parameters into anatomical clusters. Simlets fit together like Lego blocks and so form the basis for the interface that allows surgeon-educators to themselves create touch-enabled VR training units [3]. Simlets are uploaded to a cloud-based database.

3 Result

The author-level interface represents a layer of abstraction that insulates the surgeon-educator's high-level specification of the surgical steps from the technical details of the physical simulation and visual presentation. Our approach splits the scene creation work into a developer level where numerical simulation routines are selected or adjusted; the artist level where compatible geometry, collision and physics models with their default parameters are packaged into anatomical clusters, called simlets; and the author level where scenarios are created by selecting simlets.

The author-interface then follows the standard task-based approach in surgical education: a surgical procedure is specified as a series of steps, each of which consists of sub-tasks with their safety concerns. This task list is input in a fixed format: *action, anatomy, tool, safety, comment.* For example, the quintuple can be: Tear, fatty tissue, Maryland dissector, not close to vena cava,

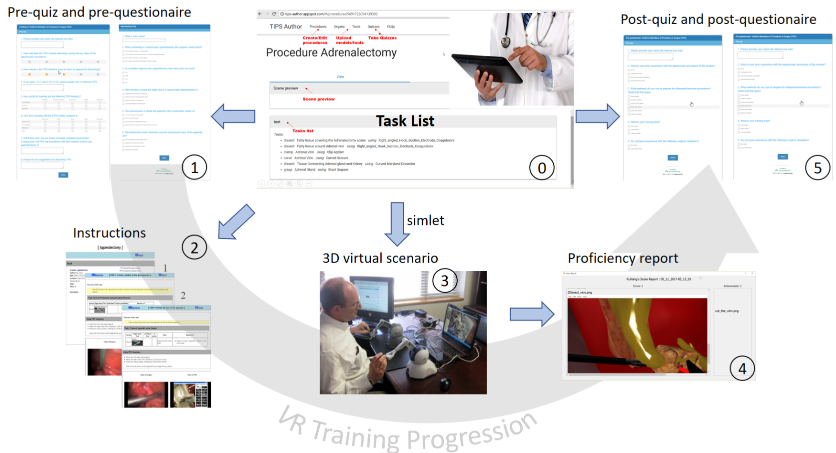

Figure 1: VR training progression.

youtube-url. Auto-suggestion while typing guides the author towards stored simlets. For missing simlets (anatomy) the author enters pointers to videos or images in the comment slot.

The task list serves four functions. (1) Peer review and collaborative determination of scope among specialists: to give early feedback and to reach consensus on the basic steps of the VR unit. (2) Generation of instructional page templates: to serve as a scaffold for authors and to ensure that instruction is consistent with the peer-reviewed task list. (3) Initialization of the simulation scenario from simlets. (4) Enable sharing of training modules among specialists as lightweight pointers to simlets: this simplifies dissemination and enables educators to efficiently create variants of anatomy, pathology or surgical approach.

While safety criteria based on proximity such as 'not cauterize near vena cava' are embedded into the simlet, more subjective criteria 'not use excessive force' have their ranges determined by comparison with two or more virtual surgeries performed by the author.

4 Conclusion

To date, junior surgeons are exposed to only fraction of the full spectrum of laparoscopic procedures and scenarios in the OR. Engaging surgeons as authors promises greater variety, specialization and relevance of laparoscopic VR training.

The TIPS-author interface is a first step in this direction. It offers, for the first time, a high-level software infrastructure for authoring soft-tissue touch-enabled VR training units. The task list assembled by the author auto-initializes the VR training progression (see Figure 1) including pre-quiz and questionnaires, instruction pages, the interactive haptic virtual simulation scenario, the proficiency report, and the post-quiz and questionnaire.

The interface has successfully been used by surgeon-educators to create a number of variants of laparoscopic training units for appendectomy, cholecystectomy and adrenalectomy. Residents were able to train with the resulting units with minimal introduction, provided by TIPS. Residents found the visual feedback easy to interpret and the resulting simulations useful for understanding critical steps of the laparoscopic procedure. By publishing the touch-enabled VR training units under the author's name we have observed good buy-in and quality control.

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