Basic Robotic Course

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INTRODUCTION

The prevalence of robot-assisted laparoscopic surgery (RALS) within both military and civilian hospitals has been steadily increasing in recent years, reaching a total of over 2 million cases worldwide to date (www.intuitivesurgical.com), generating a need for effective training of the unique skills and technological knowledge required to perform such technologically advanced procedures. Of particular importance is the initial learning curve associated with acquisition of these skills by inexperienced surgeons, which has numerous implications, particularly in terms of patient safety (Hopper, Jamison, & Lewis, 2007). The acquisition of purely cognitive skills has been studied extensively, revealing learning curves that typically involve three distinct stages of skill development: a cognitive stage, an associative stage, and an autonomous stage during which expertise is achieved (Anderson et al., 1997).

The purpose of this intelligent tutoring system (ITS) is to help train physicians both the cognitive and basic knowledge of skills needed to use the most commonly known robotic surgical system, the da Vinci. This system could be used to bridge the training gap between online cognitive training materials and hands-on psychomotor skills training with simulators and robots. The ITS could provide novice and intermediate robotic surgeons with intelligent guidance in an easily accessible system to train the cognitive process and procedural steps behind fundamental robotic surgery skills.

The tutor will include cognitive material covering an introduction to surgical robotics, introduction into the da Vinci Surgical System, basics on camera control, and interrupted suturing. This ITS will be developed using the gift framework of tools and provided as a web-based course. The content for the system was collected from multiple practicing robotic surgeons who performed each tutored task using a simulator and explaining their actions, reasoning, and potential mistakes as they performed each exercise. This information was captured as video, instruction sets, and flow charts, which were reviewed for accuracy by surgeons and then used as training content within the GIFT framework. GIFT houses several modules of RALS content that interact with each other to tailor content to learners attributes and provide the content via a Computer-Bases Tutoring System (CBTS).

RELATED RESEARCH

Individualized training has been shown to be highly effective (e.g., one on one instruction) because it allows trainees to receive expert feedback, targeting the skills most in need of acquisition or remediation. However, this form of training is costly in terms of expert time, and therefore limited. This issue has been addressed within the education and military domains through the use of ITS's, which consist of advanced training software that mimics a human tutor by adapting instructional content and feedback to an individual student. An ITS capable of supporting acquisition of the cognitive, perceptual, and psychomotor skills associated with RALS could greatly reduce the associated learning curve and improve patient safety.

Beyond a one-day individualized training, RALS surgeons typically overcome the learning curve in an experiential way. Surgical trainees may encounter their first surgical experience on an inanimate training model, excised tissue, or an actual procedure with a mentor. While this method helps to improve performance with increased experience, these procedures usually take more time to complete and are associated with a greater number or errors, which may be life threatening to the patient. More recently, Virtual Reality (VR) surgical simulators have been introduced to help alleviate this issue. VR simulation was first introduced to surgical education in the late 1980s (Satava, 1993). Since implementation, VR simulators have been established as a valuable training tool for the acquisition of basic surgical skills, allowing a trainee to safely overcome the learning curve associated with new techniques while providing independent and repetitive exposure in a safe and cost-efficient environment (Chou & Handa, 2006). The application of VR simulators in surgery has proven to be essential with the development and implementation of new technology and complex devices. However, these trainers can be expensive and are typically not portable which cause issues for practicing surgeons.

ITS's have been shown to be particularly valuable for teaching complex cognitive tasks such as trouble shooting, problem solving, and resolving critical situations. As a human tutor does, an ITS continually monitors and assesses the individual student's actions, infers the student's state of knowledge, and decides on the next instructional event to maximize the student's learning based on an embedded student model, expert model, and domain model (Perez et al., in press). As highlighted by a recent meta-analysis (Kulik & Fletcher, 2016), research and development within the domain of ITS's has demonstrated the technical feasibility and relative effectiveness of computer-based adaptive instruction as compared to classroom and small group instruction. ITS development has been applied across multiple domains, including within military applications such as ship handling and tactical decision-making. Furthermore, previous development efforts have demonstrated the ability to effectively apply generic ITS components such as authoring tools to specific military domains (Stottler, Fu, Ramachandran, & Jackson, 2001; Sottilare & Holden, 2013). Offering a portable, customized, repeatable tutoring system for RALS would be highly beneficial.

Medical ITS's

Most of the literature on medical ITS use a pedagogically approach to train knowledge-based medicine (Crowley et al., 2007) and more recently aid in imaging recognition. One of the earliest medical ITS's, GUIDON, trained medical students about infectious diseases like meningitis and bacteremia. The objectives were to identify likely causative organisms given a patient's history, medical records, and laboratory results (Clancey, 1988). It used an interactive mixed-initiative method of dialogue where either the student or the system could be in control of how the discussion played out (Clancey, 1988; Crowley et al., 2007). Another tutor, MR Tutor, is a case-based tutoring system. This system focuses on training case similarities across patient instances. This system uses a library of radiologic images where the tutor uses statistical indices to find similarities across the collection (Sharples et al., 2000).

More recently there have been several tutors developed to train on specific diseases, including diabetes's and stomach disease (Almurshidi & Naser, 2017; Almurshidi & Naser, 2017b). Almurshidi and Naser's latest tutor aims to train medical students about multiple stomach diseases. This tutor allows the learner to navigate through the domains of concepts with knowledge checks within. If the student scores a 75% or higher, they may move to the next level of difficulty, if not, they return to repeat the same set of exercises/content review. This method or recall and rehearsal provide repeat exposure to students that have yet to master the knowledge or skills.

The RALS domain represents a complex task environment involving cognitive, perceptual, and psychomotor skill components; which could greatly benefit from real-time assessment and adaptive instruction capabilities. Integration of ITS components into a RALS based course could support a reduction in both self-guided and instructor-led training, as well as a reduction in the initial learning curve observed in the first cases completed by novice surgeons, directly benefiting patient outcomes. In addition, there is a need for effective and standardized curricula and testing devices for training robotic surgeons, providing a more standardized form of guidance to all students and all learning facilities. In addition to initial acquisition training, such a curriculum could be applied to the refresher training learning curve that occurs after periods of nonuse.

ITS DESIGN and STRUCTURE

The original design of the Robotic Suturing ITS was aimed to train surgeons the cognitive, procedural, and psychomotor skills associated with two basic robotic tasks (i.e., suturing and camera control). However, the development of such a tutor is outside the scope of this project. This tutor is now structure to provide the following:

1. Introductory information on surgical robots
2. Technical details on the da Vinci surgical system
3. Basic camera control knowledge
4. Limited basics on suturing with the da Vinci system.

This iteration of the system uses a mastery learning technique to ensure the learner has satisfactory recall and can apply perquisite knowledge before proceeding to the next concept to be covered.

Opening Assessments

Before the course begins, the learners will be asked to complete a demographic survey. This survey is used to collect information about the learners, their specialty, and experience level. This iteration of the system used the demographic survey to collect information only and is a non-actionable questionnaire. As other iterations are developed, the demographic questionnaire may be used as an actionable survey that could in return affect the flow of the course content. For example, if the learner has selected otolaryngologist (i.e., Ear, Nose, and Throat surgeon) as their specialty the course environment can take action and change to provide material for this specialty. In this case, ENT surgery requires little suturing and more energy application, so the suturing content will not be as imperative to this student as others.

Due to the ambiguous training associated with surgical robotic programs, the course will then provide a mandatory actionable knowledge assessment (Figure 1). This assessment is used to measure the learner’s prior knowledge on the course objectives. At least one question from each course concept is covered in this assessment.

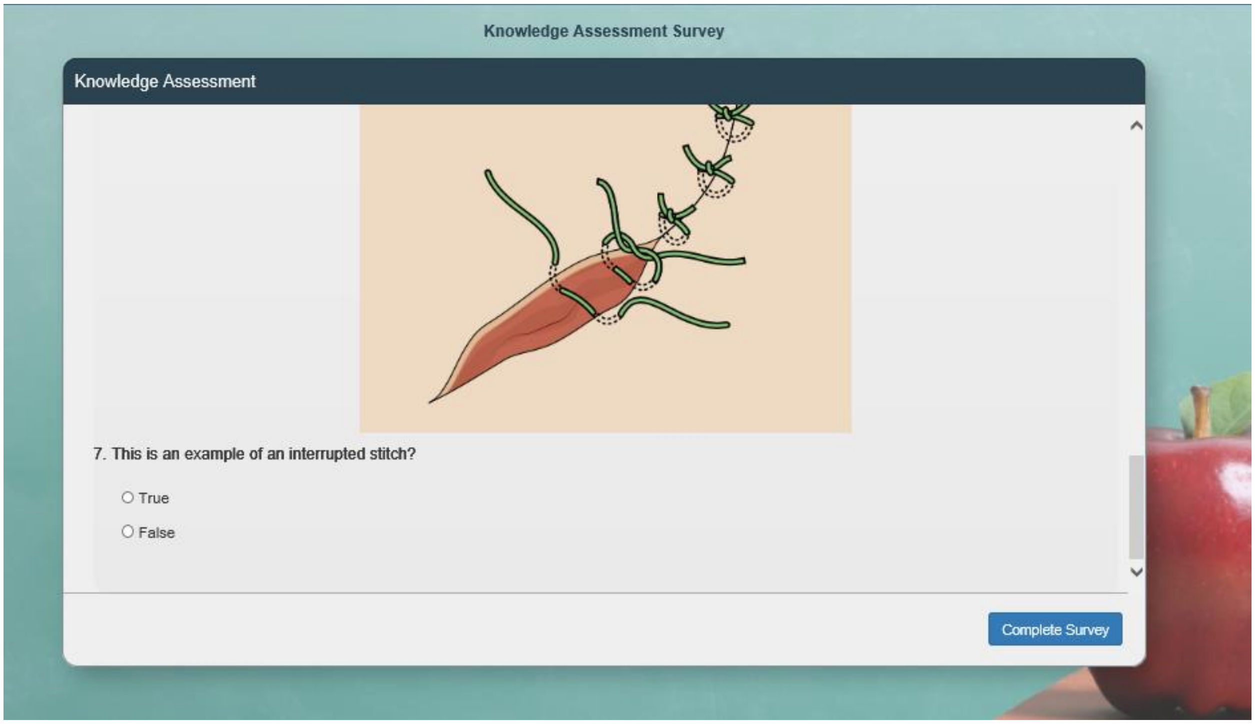

Figure 1. Knowledge Assessment Survey Sample

Course Material

As mentioned previously, the da Vinci system now provides a piece of technology that most practicing surgeons will not have any experience with. Before training the skillset to overcome this learning curve, the learners should be familiar with robotic surgery in general. The course starts with basic text explaining the difference between traditional minimally invasive surgery (MIS) and RALS. This portion will be a short mandatory object of the course. The learner will then be presented with a basic overview and history review of the introduction of robotic surgery and how the da Vinci system was brought to fruition. Because the history of surgical robotics is extensive, a conversation tree was selected to help train this material and maintain learner engagement. The conversation tree used looping pathways. The student selects which early robotic system they would like to learn about, then must select another off of the list, eventually moving their way to the end of the tree (Figure 2).

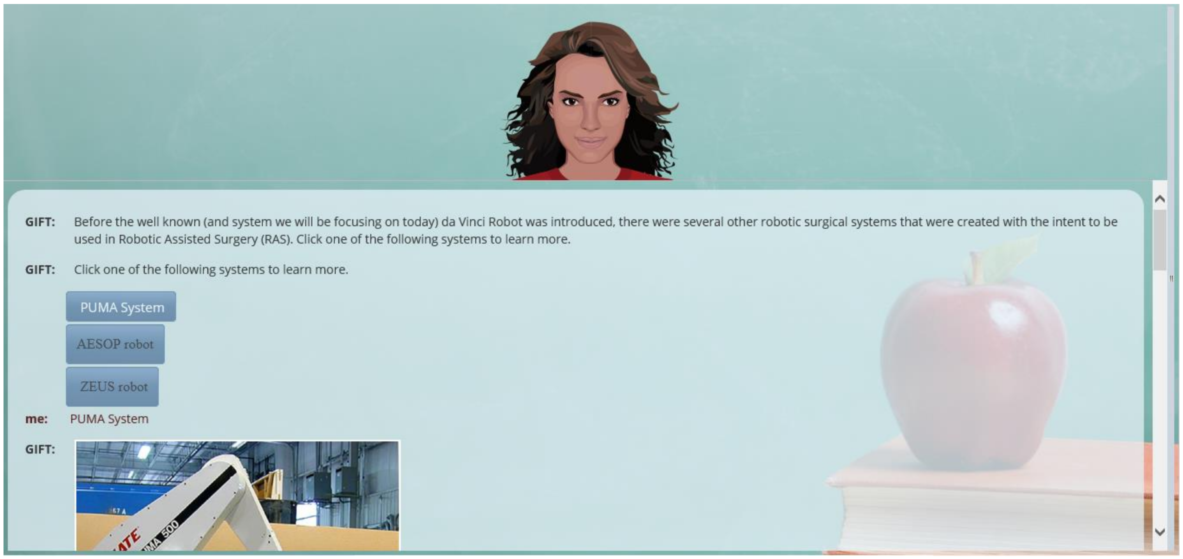

Figure 2. Conversation Tree sample.

The main attributes of the learner were based on knowledge checks. If the learner's knowledge were classified as "Novice", the content was more engaging and showed diagrams/pictures. If the learners were classified as "Experts" the course adapted to show more concise textual content. Student's knowledge was the main attribute driving the course flow and content. Figure 3 shows the course layout and flow.

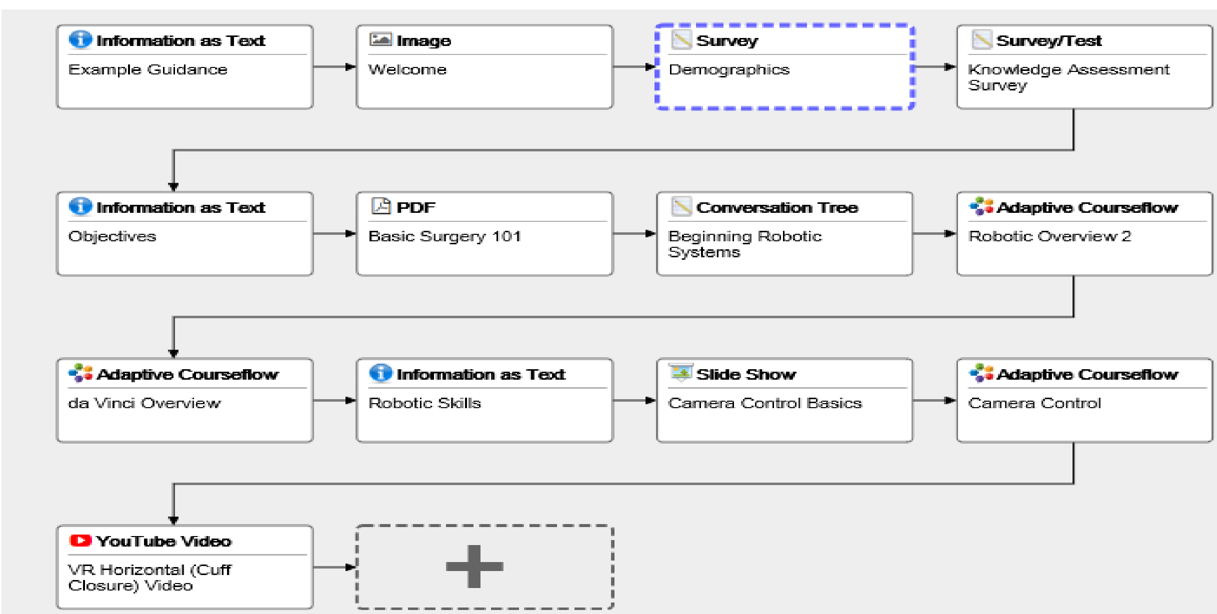

Figure 3. Course Flow

If the student does not do well on knowledge checks via a short questionnaire selected from a larger course question bank, then the student is provided with a more extensive version of the particular concepts content.

The next learning objective is aimed to train basic technical knowledge needed to use the actual da Vinci Surgical System. The answers collected from the knowledge assessment will drive the content for this section of the course as well. If the student scores poorly in the introduction assessment they will be provided with a detailed, but more engaging (e.g., video overview) content delivery. Consequently, if they learner does well on the opening assessment the tutor will provide traditional textual content as review content. After the initial mandatory content, the learners will be provided with a short questionnaire to gage their knowledge, leading back to the original or differing training material if they scored poorly or moving them to the next concept if they scored well. This adaptive course flow helps to provide tailored content specific to the learners existing and acquired knowledge.

To break up some of the textual content a slide show covers the basics of the next objective, Camera Control. The slide show provides images and text to help maintain learner engagement and provides basic technical information regarding the scope for the da Vinci system. The adaptive course flow for this concept mirrors the flow for the basic robotics and da Vinci Surgical System concepts. The camera control adaptive course flow and the suturing content will need further development in order to achieve training psychomotor skills. Figure 4 shows an example of the course content for Camera Control.

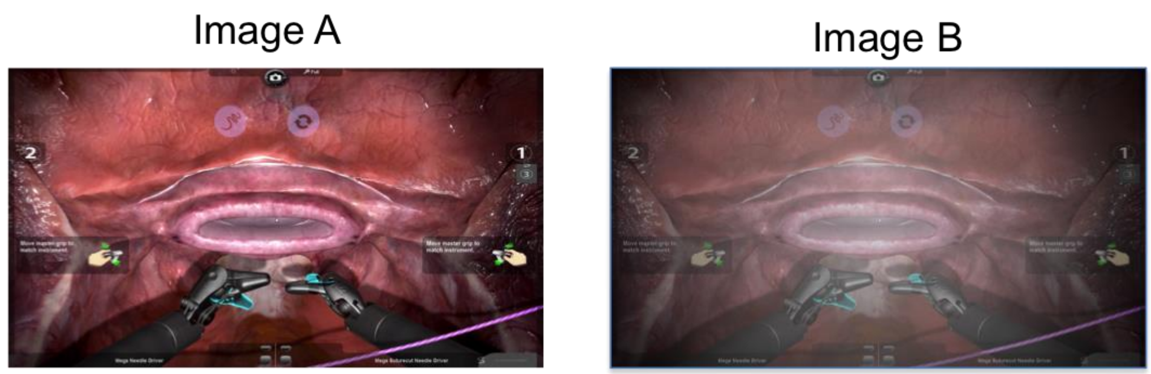

Figure 4. Example of Camera Control content.

Before the tutor moves into attempting to train the psychomotor suturing skill set, a simulated video will play for all students. This video shows a simulated vaginal cuff closure completed robotically (with a robotic surgical simulator). This is a common robotic assisted procedure. This procedure was chosen as course material because it requires camera movement and control and requires the surgeon to complete a cuff closure using an interrupted stitch. This stitch is common, but difficult for novice robotic surgeons. A video was selected to provide the learner with an all-encompassing example of what the tutor is aiming to help train. That is, the video shows why a technical overview of the system is imperative, the importance of camera control, and how an adequate interrupted suture in complete.

DISCUSSION AND RECOMMENDATIONS

GIFT as the authoring tool for developing the cognitive concepts associated with robotic surgery was user friendly. The drag and drop concept was beneficial for course flow planning and content development. However, future iterations of the robotic tutor (including more psychomotor training) will be difficult for a developer with little programming experience or limited GIFT experience. For challenging content the developer must be well versed with this authoring tool. Choosing such a complex topic to train is difficult within this system (and potentially others) because of the psychomotor, procedural, and variance of surgical specialties. For example, suturing for a general robotic surgeon will differ from suturing for a gynecological surgeon.

There are several aspects of GIFT that weren't clearly defined during my experience. For example, the question bank concept. After creating the tutor, I know understand that the question bank in used within the adaptive course flow concept, but why would the question bank be it's own concept? As I am sure this has a used within authoring, it was unclear during this development. Creating a more extensive user guide on how to use, when to use, and why to use each concept would be highly beneficial.

Developing a more simplistic, or just one portion of this course, is ideal for novice GIFT users. The authoring tool offered multiple media outlets, supports a substantial amount of content, but a novice user may not know how to integrate any "bells and whistles." The robotic tutoring system could have benefited from including highlighting clues during assessments or interaction within a video. GIFT may be capable of such features but was not easily defined on how to implement these high level capabilities.

While the initial scope of the project was aimed to provide step-by-step instruction for completing an interrupted suture, this was unmet during the scope of this project for two reasons. Reason number one, in order to train a psychomotor and procedural skill set, the developer will need additional time working with GIFT and may require an additional developer with differing credentials. Reason number two, the content for the suturing aspect of the course must be created using surgical imagery or "do's and don'ts" of robotic suturing to provide appropriate content.

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