

Desitra: A Simulator for Teaching Situated Decision Making in Dental Surgery

Narumol Vannaprathip

Faculty of ICT,
Mahidol University,
Nakhonpathom, Thailand
narumol.van@student.mahidol.ac.th

Peter Haddawy

Faculty of ICT,
Mahidol University,
Nakhonpathom, Thailand
peter.had@mahidol.ac.th

Siriwan Suebnukarn

Faculty of Dentistry,
Thammasat University,
Pathumthani, Thailand
ssiriwan@tu.ac.th

Patcharapon Sangsartra, Nunnarin Sasikhant, Sornram Sangutai

Faculty of ICT,
Mahidol University,
Nakhonpathom, Thailand
{patcharapon.san, nunnarin.sas, sornram.san}@student.mahidol.ac.th

ABSTRACT

Use of simulation to teach decision making in surgery is challenging partly due to the situated nature of the decisions, with situation awareness playing a critical role in making high quality decisions. Thus simulation systems need to be able to provide the key cues needed in making decisions with high fidelity. In this paper we present the first version of Desitra, a simulation environment for teaching decision making in dental surgery. System design was driven by an observational study of teaching sessions for endodontic surgery in the operating room which identified perceptual cues used in decision making as well as tutorial intervention strategies used by surgeons. Desitra provides an open environment for learning decision making – students carry out dental procedures and are free to make mistakes. The pedagogical module monitors the student actions and intervenes when students make mistakes, providing as little guidance as necessary to keep students on a productive learning path. The system is implemented to run on Android tablets to be maximally accessible. Preliminary evaluation of the system shows that Desitra effectively captures key perceptual cues.

Author Keywords

surgical decision making; surgical simulation; serious games; intelligent tutoring systems

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INTRODUCTION

Surgical skill training has been traditionally based on the Halstedian apprenticeship model [10] whereby the surgical trainee attempts to perform a task with guidance and close supervision from an expert surgeon [20]. But shortened training programs, reduced working hours for residents and limitations on available operating room time [9] have strained this model and interest has concomitantly increased in use of simulation for training. Surgical simulation has the potential to provide students with increased training time outside the operating room, objective assessment of procedures, and formative feedback without the need for close direct supervision of experts in limited supply [17]. But despite the fact that 75% of the important events in the operating room are related to decision making and only 25% to technical (psychomotor) skills [15], a statistic that holds in the more specific context of dental surgery as well [3], work on surgical simulation has focused mainly on technical skills and has not fulfilled its potential in supporting teaching of decision making skills [1]. In this paper we focus on surgical decision making, which is the ability to consider available options, choose the option appropriate to the situation, implement the selected option, and review its outcome [4]. Decision making in surgery has a number of distinct characteristics which make it particularly challenging, including high stakes, uncertainty of outcomes at the level of individual patient, and potential irreversibility [13]. While decision making is involved in all three phases of surgery: pre-operative, intra-operative, and post-operative, our focus is on intra-operative decision making. Intra-operative decision making has the important

aspect of being situated – situation awareness is a key component of decision making and decisions are made in the context of carrying out psychomotor tasks, which provide important context and information for the decisions.

While some computer-based systems for teaching decision making skills have been developed [5,7,11,12,16,18], insufficient attention has been given to directly supporting perceptual cues as well as teaching strategies that instruct students in how to use them. The importance of understanding cues in surgical decision making has been emphasized by Sevdalis et al [13]. In this paper we present the first version of Desitra, a simulation environment for teaching decision making in dental surgery. System design makes use of an observational study of teaching sessions for endodontic surgery in the operating room which identified perceptual cues used in decision making as well as tutorial intervention strategies used by surgeons. Desitra provides an open environment for learning decision making – students carry out dental procedures and are free to make mistakes. The pedagogical module monitors the student actions and intervenes when students make mistakes, providing as little guidance as necessary to keep students on a productive learning path. Pedagogical emphasis is placed on how to reach good decisions rather than on simply memorizing the details of a given surgical procedure. The system is implemented to run on Android tablets in order to be maximally accessible. Evaluation of the system shows that Desitra effectively captures key perceptual cues.

DECISION MAKING IN SURGERY

Surgical procedures are organized into three basic phases: pre-operative, intra-operative, and post-operative. In the pre-operative phase, the patient's condition is diagnosed, the objective of the procedure is defined, the surgical plan is developed, and the needed tools, equipment, and materials are selected and prepared. Surgical planning is a hierarchical process. The plan created in the pre-operative phase is a high-level plan, with the specific way in which each action is executed determined in the intra-operative phase when the relevant perceptual and other information is available. This form of abstract action instantiation is the primary type of decision made in the intra-operative phase. The other two types of decisions, which are closely related, are how to recover from errors and how to respond to unexpected events. The focus of the current paper is on teaching the first type of decision, with the other two types left for a subsequent version of the system.

In this paper we illustrate key concepts using the procedure of root canal. Root canal was selected because it is a complex procedure involving a variety of qualitatively different steps and requiring perceptual judgement dependent on patient anatomy information that is not fully available preoperatively. The root canal procedure includes six main stages: rubber dam application, access opening, length determination, mechanical intervention, trying

master cone, and root canal obturation; each with several steps. While the plan is created in the pre-operative phase, low-level details are determined in the intraoperative phase. For example, the first step of access opening consists of initial drilling. For this step the endodontist must evaluate the patient's radiography, select the correct type of bur with the appropriate size head corresponding to the pulp chamber width, determine the appropriate depth of drilling, and determine the side of the tooth from which to drill. The drilling must follow the correct outline shape to open access to the root canals in the pulp chamber without unnecessarily removing tooth mass.

RELATED WORK

Servais [12] provides an approach to teaching intraoperative decision making by asking students to answer questions concerning actions to be taken. After any error in judgement the student is informed of the consequence and asked to reevaluate. LapSkill [11] provides video clips of stages of laparoscopic surgery and asks students to answer multiple choice questions related to the situation shown in the clip. Flowers presents a 3D simulation using SECOND LIFE™ [5] which portrays a real life clinical scenario. It focuses on social interaction in patient management.

SICKO [7,18] is a non-immersive game for teaching patient management and clinical decision making. Players select a patient to manage, order tests, diagnose the patient's condition, and determine whether to prescribe medication or to send for surgery. If surgery is chosen, the player answers multiple choice questions to select the appropriate actions. When a player chooses a correct action, score points are given with positive feedback for positive outcomes. If an incorrect action is chosen, score points are deducted. The effect is shown to the player and the player is not given the chance to correct the action. The patient's status dynamically responds to the interventions chosen by the player. The dynamic intraoperative environment in SICKO allows players to deal with unexpected events over time.

SimPraxis [16] provides a simulated environment for teaching pre- and intra-operative decision making in laparoscopic surgery. In the intra-operative setting, students select instruments and instrument placement. When the chosen action (instrument and location) is correct, positive feedback is provided and a video clip plays showing the portion of the procedure using that instrument. When an incorrect action is chosen the effect of the action is explained and students must try the step again. Video clips are produced from actual surgical procedures and thus provide a high level of realism. However, the fact that video clips need to be obtained from real surgical procedures in the operating room limits the ability to support variations on procedures, to show outcomes of errors, and to provide practice for unexpected events.

OBSERVATIONAL STUDY

An observational study of five teaching sessions of root canal treatment was conducted at the student clinic in the Faculty of Dentistry, Thammasat University. Each surgical trainee carried out root canal treatment on a patient under the supervision and guidance of an endodontic instructor. Actions and discussions in the intraoperative sessions were recorded via video camera and transcribed. The transcript and video were analyzed to identify key information cues for decisions, types of errors and teaching strategies.

Surgeons use various information in making intraoperative decisions, including patient information, medical knowledge (anatomy, physiology, and pathology), surgical procedure knowledge, and visual and tactile perceptual information. From the observational study and interviews with endodontists we identified the information used at each decision step in the procedure. This information was used to inform the design of the simulation and the content of the feedback messages. For example, after selecting the outline shape to locate the canal orifice before beginning drilling, there should not be any fracture on the patient tooth (visual and experience). The surgeon selects the drill type (surgical procedure), the drill size by evaluating the patient's radiography (visual, patient information), the drilling depth (surgical procedure), the entry point to drill (visual, medical knowledge, and surgical procedure), and the direction to drill (visual, medical knowledge, and surgical procedure).

Three types of procedural errors were observed: errors in selecting an action, errors in dealing with unexpected events, and mistakes in recovering from errors. In this paper, we focus on the first type.

In a study of a large variety of surgical procedures Hauge [6] identified 27 teaching behaviors in the operating room, covering the spectrum of operating room activities. Our thematic analysis of the teaching sessions for root canal treatment [19] showed seven of these to be used: give guidance, give order, provide demonstration, give assistance, give hint, give explanation, and give feedback. These were often used in combination. Instructors responded to student errors with a variety of strategies. The factors that most influenced feedback for errors were the number of sequential errors committed in that stage, the criticality of the step, and the remaining time to carry out the procedure. Time and criticality (which tend to trigger giving an order or assistance) are important factors primarily due to the use of real patients, so we focus on the number of errors. For the first error instructors gave feedback and typically provided guidance by simply informing the student of the error and the possible consequences. For the second error in a stage, the instructor additionally provided more specific information about such aspects as surgical technique. For the third error, instructors would typically intervene by demonstrating how the action should be carried out while providing verbal explanation.

SYSTEM DESIGN

Simulation design

The simulator provides an intraoperative environment in which the student can see the patient from a facial view and a close up view of the working tooth. The upper right corner of the screen provides radiography and patient case information. The student can view the enlarged radiography to assess the anatomy of working tooth, as in Figure 1. The student performs a surgical task by selecting tools from the horizontal scrollable tray at the bottom of the screen, and placing them in the preparation tray or on the working tooth. Figure 2 shows the simulator immediately after the student places a drill on the working tooth. The system requests the student to specify the drilling depth (vertical slider or real value), drilling entry point, and drilling direction (drop down menus).

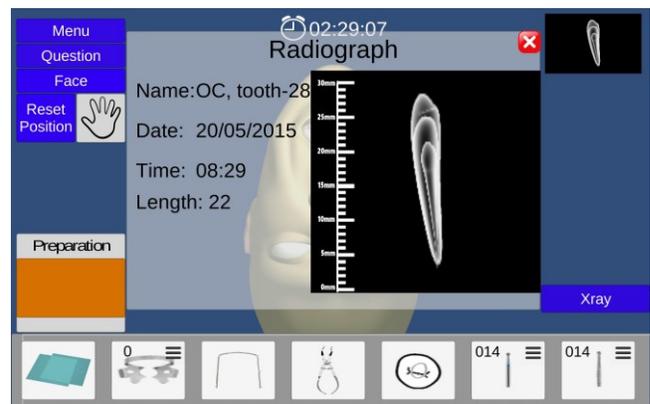


Figure 1. The enlarged radiograph panel allowing student to assess the anatomy of working tooth with patient's information.



Figure 2. Close up of working tooth (with rubber dam applied) showing the information the user must specify as part of the drilling decision stage.

Teaching strategy and error handling

The first time an error occurs in a stage Desitra uses the giving guidance strategy by explaining the consequence of the error and displaying an image when relevant. The second time the student makes a mistake, the system again gives guidance but with additional specific information e.g.

the surgical technique. If a third mistake is made, the system demonstrates the correct action(s) accompanied by verbal explanation.

For example, suppose the student is at the initial drilling stage and has selected the safe-tipped taper bur (incorrect tool type) with tool number, drilling depth, entry point for drilling, and direction to drill. The system displays the error message: “You are using a safe tipped taper bur as the initial drill. The safe tipped taper bur can be damaged and the tooth is at risk of being fractured.” If the student tries again by selecting the round diamond bur but the tool number is too large, a second error message is displayed explaining how to select the proper size along with an image of the consequence of the error as shown in Figure 3.



Figure 3. The second error message when too large drill was selected.

IMPLEMENTATION

We follow the basic ITS architecture of user interface, student model, pedagogical module, and the domain knowledge repository [2,8]. The simulator is the user interface component which sends a data stream of student actions to the student model. Currently the student model only keeps a record of the actions. The domain knowledge repository stores the sequence of all actions in the procedure. The pedagogical module checks the correctness of student actions against the domain knowledge and generates interventions according to the teaching strategy described above.

As shown in Figure 4, the system design follows the gaming ITS architecture of Sottolare [14]. The Unity game engine is used for simulation using 3D tool and patient models produced with MAYA. The tutoring modules reside in the android engine plugin. Desitra is designed to run on Android tablets in order to provide maximum accessibility to users. While a richer simulation including tactile feedback can be achieved using a virtual reality environment, the increase in usability and low cost were factors driving our choice of the tablet platform.

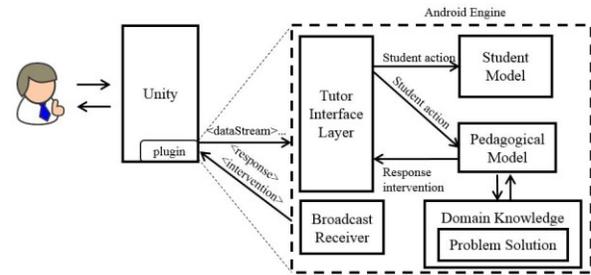


Figure 4. Desitra implementation architecture.

EVALUATION

We sought to determine the extent to which Desitra captures the key perceptual cues at the various decision stages. A stage of rubber dam application and two sub steps of access opening including outline drawing, and initial drilling were selected for evaluation since they represent a variety of decisions. Two expert endodontists were each asked to identify the important perceptual cues and other information needed for decision making for each of these three decisions. After doing so, they were asked to rate the simulation on a 5-point Likert scale as to how well it captures the cues they identified, with 5 designating excellent and 1 designating poor.

The two endodontists identified the same cues and information except that one identified tactile information as important for decision making in the initial drilling stage while the other did not. In terms of how well the system rendered the identified cues, both found the simulation did well (score 4-5) in providing information concerning the state of the working tooth, outline on the tooth, the radiograph, patient case information, and the tools. They disagreed on how well the system conveyed the stage of the procedure (scores 3 and 5). In the case of the initial drilling stage, one endodontist scored the drilling information 5 while the other gave a score of 3 because he wanted to see drilling motion which is not rendered in the simulation.

CONCLUSIONS AND FUTURE WORK

Our initial evaluation of Desitra suggests that it does a good job of capturing most of the key perceptual cues for the decisions in the three stages evaluated. The interventions in the pedagogical module of Desitra place emphasis on how to reach good decisions rather than on memorization of surgical steps. Although the current version is limited to the root canal procedure, the tutoring strategies used are fully general. Future work will focus on covering more procedures, adding a student model to personalize tutorial interaction, automatically generating content of interventions based on a causal domain model, and evaluation of effectiveness in teaching intraoperative decision making.

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