

Intelligent Clinical Training Systems

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Clinical medicine is one of the most challenging areas for education. The development of clinical competence requires the assimilation of large amounts of knowledge combined with acquisition of clinical skills and clinical problem-solving ability. Clinical skills include the technical skill in implementing a procedure as well as skill in patient consultation and physical examination. Clinical problem solving requires the ability to synthesize the information contained in a clinical case and to integrate it with the physician's knowledge and experience in order to diagnose and manage the patient's problem. It also requires the ability to work in teams and the ability to transfer one's knowledge to unfamiliar situations such as rare problems, disasters and emergencies.

Currently, training toward clinical competence follows an apprenticeship approach, which consists of close expert supervision while interacting with patients. This method of training can subject patients to discomfort, risk of complications, and prolonged procedure times, creating a clinical governance dilemma. At the same time, there may be limited access to apprenticeship training in more complex scenarios with corresponding difficulty training in a time-effective manner. Intelligent clinical training systems hold the promise to address many of these issues. A facilitating technological environment has emerged in recent years through the maturation of research in intelligent tutoring systems, medical simulation, and virtual reality (VR) techniques and the develop-

ment of Web 2.0 collaborative authoring and social networking tools.

The field of intelligent tutoring systems has come a long way since its start in the 1980s. There is now a well accepted standard architecture for such systems [1] and a number of well developed and tested user modeling techniques such as Bayesian networks [2]. The field has matured to the extent that Carnegie Mellon University is now using intelligent tutoring as a key technology in its ambitious Open Learning Initiative [3]. Recent work on incorporating medical ontologies into intelligent tutoring systems [4] and on leveraging existing large-scale medical ontologies like UMLS [5] hold promise to increase the domain coverage and quality of interaction and to decrease the cost of producing such systems.

Clinical training during the past decade has witnessed a significant increase in the use of simulation technology for teaching and assessment [6]. Medical simulations, in general, aim to imitate real patients, anatomic regions, or clinical tasks, and/or to mirror the real-life circumstances in which medical services are rendered. The simulator response will vary according to user actions (for example, heart rate and blood pressure will change appropriately depending on the dose of a particular drug administered intravenously [7]). Training and assessment using these simulators can focus on individual skills (e.g., ability of a resident to intubate [8]) or the effectiveness of teams [9, 10].

The use of virtual and augmented reality techniques to create realistic simulations of the physical aspects of the clinical environment is attracting increasing attention due to the promise of creating high-quality training environments, and to the rapid development and decreasing cost of software and hardware, driven in part by developments in the computer game industry. Building upon successful VR simulations in specific areas [11–13], a stream of work has emerged to build generic open-source software toolkits for medical VR

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simulation [14–17]. These emerging toolkits should help to speed the development of high-quality VR simulations for surgical training.

This special issue on intelligent clinical training systems contains four papers that show how these advances in technology are enabling advances in clinical training and conversely how the challenges of the clinical training environment are driving development of new technology. The papers highlight issues in the design and construction of systems for training in clinical problem solving and clinical practice and the challenges in the integration of such systems into medical school curricula.

The paper by Buyl and Nyssen [18] presents the MedSkills system that supports the practice of evidence-based medicine. MedSkills provides a flexible environment for authoring and making use of evidence-based knowledge for education in medical skills for all levels of healthcare professionals. The system makes use of a wiki that allows registered users to add, adapt, and correct content. The system organizes knowledge into cellular, organ, body, and best treatment knowledge maps and can support multimedia content. MedSkills currently encompasses knowledge in the areas of chest pain, respiratory problems, shock, burns, birth, and minor surgery and is currently used as an educational tool by several groups in Europe.

The paper by Rhiemora et al. [19] presents and evaluates a prototype virtual reality simulator for teaching dental procedures. The system includes haptic feedback that can simulate tooth surface exploration and cutting for tooth preparation. The work makes first steps at integrating virtual reality surgical simulation with intelligent tutoring capabilities. It is able to monitor and classify the performance of an operator as novice or expert. It allows procedures to be visually and haptically recorded and replayed so that procedures as carried out by experts may be used to guide students.

Hayes-Roth et al. [20] describe STAR Workshop, a Web-based training system that automates efficacious techniques for individualized coaching and authentic

role-play practice. Several patient design features enhance role-play authenticity by replicating important human qualities and functional requirements of real patients. This study compares STAR Workshop to a Web-based, self-guided e-book and a no-treatment control, for training the Engage for Change (E4C) brief intervention protocol to reduce alcohol use. The results suggest that STAR Workshop is an accessible, scalable, cost-effective approach to training clinical interviewing skills.

Berner and McGowan [21] survey the literature and discuss the issues in the use of diagnostic decision support systems in medical education. The authors illustrate some of the issues that will be faced as these types of computer systems become available for use with medical students. While students will still need grounding in the basic knowledge and skills that have always been necessary to become a physician, computer-based diagnostic programs are likely to influence the training that students receive and the manner in which they practice their craft.

A number of key technologies are coming together to enable a wave of innovation in the way that clinical training is conducted. The innovations hold the promise not only to reduce the cost of clinical training but also to increase the quality by providing a new set of pedagogical tools for medical faculty to use. The papers in this special issue provide a glimpse of this coming wave. What is needed now is strong collaboration among medical school faculty, experts in pedagogy, computer scientists, and entrepreneurs in order to bring these developments into wide-spread use.

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