Chapter 10
A Multi-Agent Simulation of Kidney Function for Medical Education

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ABSTRACT
This chapter describes a multi-agent system to simulate kidney function for the purpose of teaching renal physiology to healthcare students. Renal function is modeled with agents. Agents represent molecules and fluids and the environment represents the structures, membranes and volumes of the nephrons in the kidneys. The agents move dynamically through their environment, responding appropriately depending on their surroundings. The authors describe how this multi-agent system is used in research and teaching medical students about the renal system. Results of heuristic and usability testing by medical students show improved visualization of the function of the renal system and self-confidence in learning renal physiology.

INTRODUCTION
Renal physiology is exceptionally difficult to learn. The countercurrent exchange system of the kidney was ranked number one in basic science difficulty and number two in clinical difficulty in a 1990 survey of medical educators (Dawson-Saunders, Feltovich, Coulson, & Steward, 1990). Project TOUCH was a multiyear collaboration between the University of Hawaii and the University of New Mexico in which virtual reality (VR) applications were developed to advance medical education. One application was a 3D VR fly-through model of the kidney (Alverson & Saiki, 2006). Each kidney is composed of millions of nephrons. Our simulation shows the details of one nephron, while adjacent nephrons are shown without detail for context. The simulation prototype has subsequently been enhanced with a new user experience.
interface and gaming motifs. The new system underwent heuristic and usability tests that are described in this chapter.

The kidney’s function is to eliminate water soluble wastes from the body (Banasik, 2000). We chose a multi-agent system implementation because it results in more realistic and detailed model. Agents represent the motion of molecules and fluids within a nephron’s tubules. The agents move dynamically and intelligently within their environment to simulate different kidney function, such as water reabsorption and waste secretion.

The rest of this paper is organized as follows. First, multiagent systems and the renal system are described. Second, we describe the implementation and characteristics of our simulation system. Then the visualization of difficult concepts to aid understanding is described. Finally, the usability experiments conducted and the results obtained are described followed by future trends for agents in medical simulations and finally, the conclusion.

BACKGROUND

Multi-Agent Systems Applied in Healthcare

A multi-agent system (MAS) is composed of agents, each of which selects its own course of action based upon its goals (Weiss, 1999; Woolridge, 2002). Most definitions of agents include the following characteristics: a) An agent perceives its environment, decides on actions, and uses its effectors to perform the selected actions. b) An agent is active over a period of time, taking action based on the world it senses at the moment, c) Agents interact with one another directly through messaging or indirectly through their actions on their common environment, d) An agent has goal(s) as well as some latitude as to how to achieve those goals (Barber et al., 2003). A multi-agent system may be incorporated in a physical (robotic) body, or sense and act upon the world entirely in software simulations, or computer applications, often called softbots.

Multiagent systems have been used in a broad range of applications including soccer games (Robocup, 2008), search and rescue operations (Robocup Rescue, 2008), space (Bernard et al., 1999; NASA, 2008), and military applications (Zafar, Qazi, & Baig, 2006; Sklar, Davies, & Co., 2004) describe SimEd, a simulation of the interactions that occur among students, teachers and administrators. Their aim is to create a toolkit that will allow policy makers to experiment with their decisions.

Agents have also been used in medical applications. The journal Artificial Intelligence in Medicine recently published a special issue on software agents in health care (Moreno & Garbay, 2005). IEEE Intelligent Systems and AI Communications did similar special issues recently.


Most agent applications in medicine, including those above, are focused on decision-support for physicians and/or patients. In contrast, the goal of our system is to teach physiological concepts to health care professionals. When health care workers have a better understanding of the physiology of the human body, they can also understand the effects of disease processes in patients, which
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