A Sketch Interactive Approach to Computer-Assisted Biology Instruction

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ABSTRACT
Existing computer-assisted instructional (CAI) techniques for introductory biology are presently restrictive in scope, due to their focus on utilizing drills that aim for rote memorization instead of providing interaction that aids in intuitive understanding. In this paper, we discuss a prototype system for assessing learner understanding of introductory cell biology concepts using sketch-based interaction and recognition techniques.

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Biology, sketch recognition, computer-aided instruction, interactive technology, sketch interaction, education.

ACM Classification Keywords
K.3.1 Computer Uses in Education: Computer-assisted instruction (CAI).

INTRODUCTION
Properly developed computer-aided instruction (CAI) systems can enhance the effectiveness of a learning curriculum by fostering interactive involvement and assessment of learners using supplemental educational materials [6]. One curriculum example, introductory biology as taught in secondary and university curriculums, lends itself well to use of such a CAI system. The nature of the curriculum is traditionally rote memorization, yet there have been many efforts to supplement it with interactive multimedia for improved visualization and learning. In the simplest case, CAI systems could be ideal tools for preparing learners for biology advanced placement exams and for foundational knowledge assessment to help gauge further study in other fields.

One way to engage learners in the instruction of introductory biology concepts involves incorporating a sketching component into the learning process, since it stimulates learners to directly visualize the concepts that cannot be conveyed through standard textbook reading alone. An interactive sketching approach (i.e. sketch recognition) has been implemented successfully in similar systems specific to other subjects such as mathematics (e.g., MathPad^2 [3]) and chemistry (e.g., ChemPad [5]). While CAI systems unique to introductory biology have existed for several decades [1], current systems lack any sort of sketch-based interactivity component. This limits such systems to offer little more than "drill-and-kill" techniques already provided in paper-based assignments and textbook learning [6].

We wish to explore the feasibility of sketch-based interaction for use in introductory biology CAI systems. Therefore, we have developed a prototype system that utilizes sketch recognition tools to allow students to naturally sketch biology concepts for later feedback and assessment on their comprehension. An example session of our system in use can be found in Figure 1.

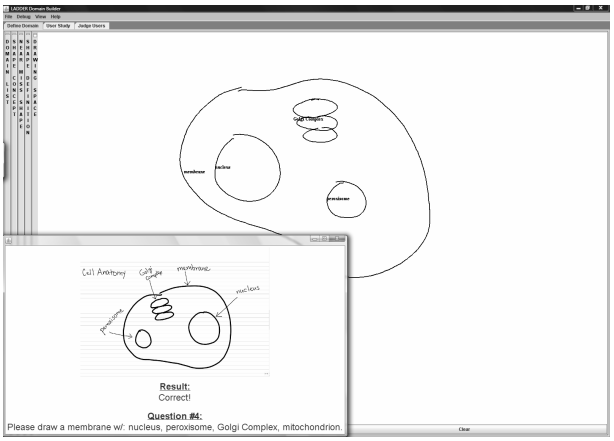

Figure 1. Screenshot of biology sketch system.

IMPLEMENTATION
One of the most important aspects for including a sketch-based interaction component in a CAI system for introductory biology is for learners to freely sketch the graphical responses to posed questions. Requiring learners to know special symbols or gestures specific to the application and not relevant to the topic at hand is counterproductive. Therefore, our system utilizes the

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PaleoSketch recognizer [4] for recognizing and approximating learner sketches, as well as the LADDER sketching language [2] for identifying the geometric properties of and the spatial relationships of the geometric approximations generated from the recognizer. We created our specific introductory cell biology learning application in Java, which allows for use on any platform.

EVALUATION AND PILOT USER STUDY

We first evaluate the sketch recognition capabilities of our CAI system by collecting test data from eight engineering students from the graduate school. The evaluation consists of prompting users to sketch variations of cells used in our application for a total of thirty-two sketches. Of those sketches, our system correctly recognized thirty variations of cell membranes for a total accuracy of 93.75%.

Cell Membrane Variants	Accuracy
w/ Nucleus	100%
above w/ Peroxisome	100%
above w/ Golgi complex	75%
above w/ Mitochondrion	75%

Table 1. Individual accuracies of cell membrane variants.

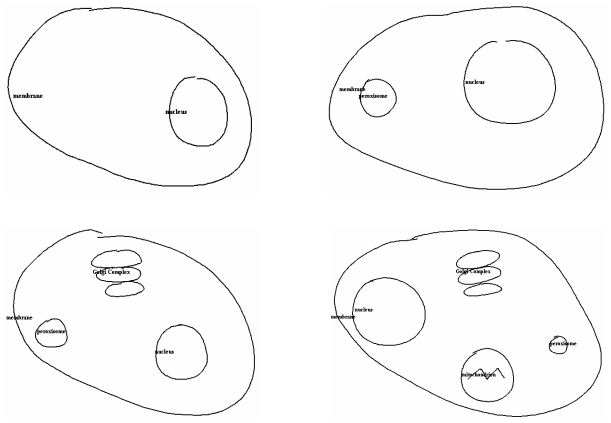

Figure 2. Correct sketched input for tested biology concepts recognized by our system.

We then developed a pilot user study to evaluate the value of our system for teaching introductory cell biology. The user study involved ten users being asked to sketch a cell membrane with a variety of cell components. The users were prompted during the use of the application to freehand sketch variations of a cell layout that included the nucleus, the peroxisome, the Golgi complex, and the mitochondrion (Figure 2). After the user completed each sketch, our system assessed the input by first recognizing the cell components, then evaluated whether the components match the given prompt. A final follow-up feedback response to the user on the correctness of the solution was then given.

FUTURE WORK

The primary focus our CAI system development at the moment is determining the expandability of sketch interaction in applications geared towards the introductory biology curriculum. The next step in the work proposed in this paper is to extend the system for other biology concepts that would benefit from sketching, such as anatomy and physiology. We would also like to research the limitations of our system by determining what important biology concepts have difficulty being encoded with the current recognition tools utilized in our system, so that we can resolve those issues in order to make a more robust and definitive CAI system for introductory biology.

CONCLUSION

This paper presented a prototype study of a sketch-based recognition tool for learning and assessment of introductory cell biology. A pilot user study of ten participants was performed that was used to evaluate the feasibility of developing the interface and to provide insight into more advanced interface development for the system.

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