Evaluation of *MorphologyNet* as a Virtual Dissection Experience

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Abstract: As technological developments in the field of medical imaging increase at an exponential rate, literally hundreds of researchers and clinicians are generating three-dimensional visualizations of anatomical structures for use in research and disease diagnosis. But virtual dissection experiences (VDEs) can also be valuable for and appealing to the current video-game generation of K-16 students, and may well stimulate student interest in science. This may be particularly true if the VDE is realistic and easy to use. Herein we describe *MorphologyNet*, a VDE that provides both an interactive, anatomical dissection tool as well as a library of 3D dissectible images from several organism groups. We also discuss preliminary results of student evaluations of the usability and usefulness of *MorphologyNet* as a learning tool.

Introduction

Technological developments in the field of medical imaging are increasing at an exponential rate, and now literally hundreds of researchers and clinicians are generating three-dimensional (3D) visualizations of anatomical structures using magnetic resonance imaging (MRI; e.g., Cline et al. 1991; Ebeling et al. 1989), computed tomography (CT; e.g., Brochu 1996; Johnson et al. 1996), and serial sections (e.g., Schiemann et al. 1997; Balke & Maglia 2003). The creation and use of 3D visualizations has revolutionized the study of anatomy and physiology, and has provided researchers and clinicians with new tools to diagnose disease (Tampieri 1995), train surgeons through "virtual" operations (Taylor et al. 1999) and examine minute, complex and internal structures (Maisano 2004).

Virtual Dissection Experiences (VDEs), wherein students examine anatomy by dissecting models in a virtual reality environment, are gaining popularity in upper K-12 and university classrooms. Virtual dissection experiences can present a viable alternative to laboratory dissection for students resistant to animal dissection for moral reasons. And when used as a complement to laboratory dissection, VDEs can provide a constant and renewable source of review materials. Additionally, many VDEs provide advantages such as the examination of internal and diminutive structures not typically seen in gross dissection and the ability to examine structures from atypical perspectives (e.g., fly-throughs, walk-arounds, etc.); thus, VDEs can in some ways be superior to laboratory dissection.

Educators and students can best take advantage of the benefits of 3D digital reconstructions if they are stored in a web-accessible, easy-to-access digital library. Furthermore, if the digital library is free, available to all internet users, and does not require proprietary software, it provides a cost-effective addition to, or alternative to, laboratory dissection. In addition, the more interactive and realistic the VDE, the better chance that it will be an effective learning tool and will stimulate student interest in science.

Herein we discuss preliminary student evaluation of the usefulness of *MorphologyNet*, a VDE that provides both an interactive, anatomical dissection tool as well as a library of 3D dissectible images from several organism groups.

The *MorphologyNet* Digital Library

We have developed a NSF-supported, web-based, interactive digital library of 3D visualizations of animal anatomy called *MorphologyNet* (http://www.morphologynet.org) (Hoeft et al. 2005). Visualizations in *MorphologyNet* represent all tissue types (skeletons, muscles, nerves, etc.) and contain minute structures usually not reconstructed in digital anatomical libraries. Furthermore, the visualizations in *MorphologyNet* consist of layers representing the different anatomical structures. By showing and hiding layers, visualizations can be "dissected" as would real

biological objects. As shown in Fig. 1, users can customize images by modifying the color, texture, transparency, and lighting of each layer. Images can be resized and rotated about the x-, y-, and z-axes simultaneously (via mouse clicks and drags), and can be enlarged, reduced, and moved about the screen.

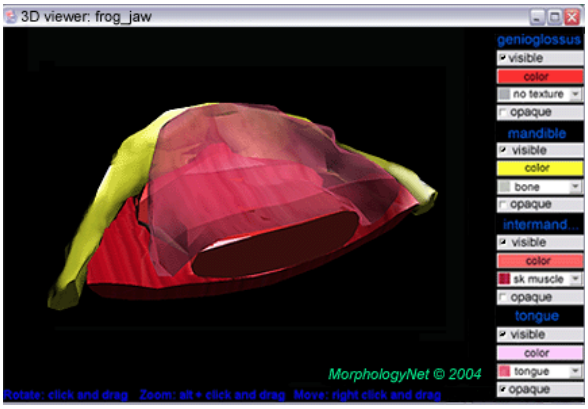

Figure 1: Screen shot of *MorphologyNet* viewer window showing a superior view of a 3D image of a frog tongue complex. Images can be rotated about the x-, y-, and z-axes simultaneously via mouse clicks and drags, thus providing unique perspectives typically not available in other VDEs. Each layer (= anatomical structure) can be customized for color, texture, and transparency, and can be made visible or hidden. Note that the tongue has been made transparent and the intermandibularis muscle has a "skeletal muscle" texture.

In contrast to *MorphologyNet,* most currently available web-based anatomical tutorials focus on human anatomy and are designed for medical or university students (e.g., Human Anaotmy Online: http://www.med.uc.edu /haonline/index.html; Anatomy TV: http://www.anatomy.tv). Thus, the usefulness for K-12 and university students studying general biology, comparative anatomy, or zoology is limited. A few anatomical libraries focus on non-human vertebrates and are designed for students at the secondary level (e.g., Virtual Frog Dissection Kit: http://froggy.lbl.gov/virtual/, Virtual Fetal Pig: http://www.whitman.edu/biology/vpd/). However, none of these libraries provides the level of interactivity or realism found in the *MorphologyNet* library (e.g., Fig. 2). Furthermore, most online anatomical browsers focus on the anatomy of one organism, and thus do not provide the functionality to compare the anatomy of several species. As a community-built digital library, researchers studying many different types of organisms are accessioning their 3D images into *MorphologyNet.* Thus, the library will house images representing all major vertebrate groups, allowing users to "dissect" one animal at a time, following along step-by-step through each anatomical system, or to compare anatomical systems across groups (much in the way a comparative anatomy course is taught). In this way, students can learn the detailed anatomy of a single organism or can focus on the function, adaptation, and diversity among groups.

MorphologyNet was developed primarily as a research tool, with the scientific research community as the target audience. However, because of its ease of use, web-accessibility, no cost, and level of interactivity, it has the potential to provide superior virtual dissection experiences for students at all levels. We are currently in the process of designing and developing an educational user-interface for *MorphologyNet*, with the hopes of revolutionizing comparative anatomy education and setting the standards for VDEs in general.

Evaluation of the *MorphologyNet* VDE for Educational Use

Our goal is to insure that the educational interface of *MorphologyNet* provides the most positive VDE possible for students. To take advantage of the existing strengths of the software, we are conducting ongoing usability studies of *MorphologyNet* in an educational context. The preliminary survey results have provided some insight into the effectiveness of the *MorphologyNet* VDE, student opinion of the experiences, and student suggestions for improvement of the software. Because these survey results will be incorporated into the ongoing improvements to the educational interface, discussion of the survey and the preliminary results is warranted.

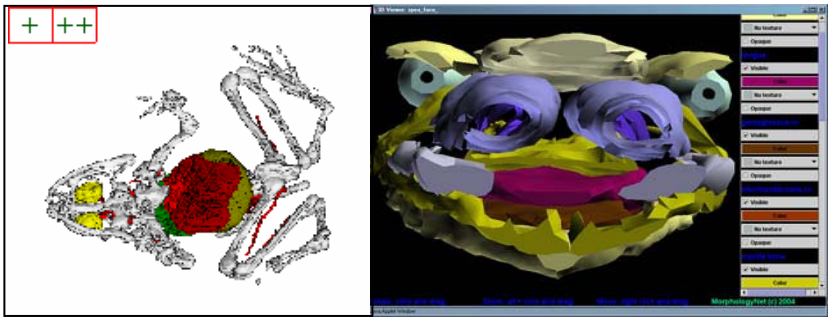

Figure 2: Left: "Dissected" frog from the *Virtual Frog Dissection Kit.* Right: Anterior view of a partially "dissected" frog face from the *MorphologyNet* digital library. Note that the *MorphologyNet* display is far more realistic, showing more substructures and with a better sense of proportionality.

The usability survey was developed following the guidelines provided by the NSF-sponsored Online Evaluation Resource Library http://www.oerl.sri.com/). The evaluation group consists of 50 university-level students with varied experience with laboratory dissection (from "no experience" to "several semesters of experience"), and who are asked to conduct an unsupervised virtual dissection of their choice using *MorphologyNet*. (Note: only twenty evaluations were available as of this writing, and the discussions below are based on them.) Students are asked to evaluate their interest and comfort level in learning anatomy, using computers, and playing video games. The evaluation also includes several questions designed to assess the user's ability to understand and manipulate the 3D visualizations. In addition, the participants are asked their opinions about the utility and importance of VDEs as an augmentation or substitution for laboratory dissection. Finally, the participants are given the opportunity to provide additional comments and feedback about the software and VDEs in general.

All of the students who responded to the survey identified themselves as at least moderately comfortable using computers, having some experience with dissection, and being at least somewhat interested in learning anatomy. More than 75% of the students felt that the *MorphologyNet* VDE could help them learn anatomy, was easy to use, and provided a realistic dissection experience. However, 12.5% of the students felt that it was difficult to conceptualize the anatomy in the virtual 3D environment and "got lost" while examining the images. More than 50% of the students felt that combining VDEs with real dissections would have helped them to better visualize and understand the anatomy, and 70% felt that the VDEs provided advantages to dissecting real specimens (identified below in the comments). However, 50% of the students preferred dissecting real specimens over virtual ones, 12.5% of the students thought the online images were difficult to visualize, and 25% of the students did not like conducting dissections online.

Some of the comments from the evaluations included:

> *The website allows people to look at parts of the anatomy that are hard to view.*
>
> *If used properly, MorphologyNet has the potential to help get a better understanding of anatomy.*
>
> *Opening a specimen is the best way to learn anatomy, but it helps you visualize what you are supposed to see.*
>
> *It is hard to make visual sense of what I'm seeing.*
>
> *I like how you can make things disappear and a reappear without losing anything. You can make different parts different colors so you can see how each part interacts with each other.*
>
> *It lets you see specimens without the damage from real dissection. MorphologyNet is fun and not real hard to understand.*

Significance to the Enhancement of *MorphologyNet* and VDEs in General

It is interesting to compare the preliminary results of the *MorphologyNet* VDE usability surveys to those of Franklin et al. (1992) who also compiled student opinions of in-class versus virtual dissections. They found that 72% of their students thought VDEs were helpful for understanding anatomy, but only 18% identified advantages of VDEs over real dissections. In addition, 44% felt that real dissections were better than VDEs. The preliminary results from our study are similar in that our respondents also found VDEs helpful for understanding anatomy, but differ in that our respondents did not clearly prefer real dissections to virtual ones---i.e., half of those responding to our survey said they preferred to conduct virtual dissections.

Best practices of user-interface design should provide an easy-to-use visual environment for revealing structure, showing relationships, and enabling interactivity (Schneiderman, 1992). As such, the *MorphologyNet* digital library viewer was designed to provide a highly-interactive experience that allows users a considerable amount of freedom to manipulate and customize models. However, it is important to note that interactivity does not necessarily equate to ease-of use and understandability in an educational VDE. As the number of available functions and the complexity of a user-interface increases, so can the difficulty a student has in perceiving position and controlling the environment.

As with the design of every user interface, the prior experiences of the user must be taken into account when developing a VDE. Those student respondents who found the *MorphologyNet* VDE to be realistic and easy to use also identified themselves as having appreciable experience with dissecting real specimens and playing video games. Thus, their prior experience with dissection and virtual reality environments likely helped the students to orient to the VDE. Similarly, users with considerable prior experience should be able to comprehend a more complex and realistic VDE.

In the case of *MorphologyNet*, the virtual dissection experiences involve research-based models that are being modified for educational use. Despite the positive preliminary usability and usefulness results that we have seen for this fairly complex visualization tool, we feel that we must proceed with caution with respect to adding even more functionality to the user interface. We realize that many of our intended users will not have had the same degree of dissection and virtual reality environment experiences as our test group. Besides limiting the complexity of the educational user interface, it is also vital that we develop age-appropriate tutorials to aid in orientation about and identification of substructures within the anatomical models. Ultimately, it is our hope that this project will not only revolutionize comparative anatomy education, but will also set the standards for VDEs in general.

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