

A Web-based Computer-aided Learning Module for an Anatomy Course Using Open Source Image Mapping Software

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Abstract: Computer-aided learning (CAL) is used increasingly to teach anatomy in post-secondary programs. Studies show that augmentation of traditional cadaver dissection and model examination by CAL can be associated with positive student learning outcomes. In order to reduce costs associated with the purchase of skeletons and models and to encourage study outside of the laboratory period, interactive web-based CAL modules were developed for a comparative vertebrate anatomy course using skulls on hand, an open source image editor, and a simple text editor. Each module featured images of an animal skull in four orientations and allowed the user to identify individual bones and bony landmarks with a mouse. Study modules and practice quizzes were made available to students through the institution's learning management system for 24-hour access.

Key words: anatomy, computer-aided, dissection, interactive, web-based

INTRODUCTION

Anatomy courses are commonly offered in post-secondary education programs and may serve as an elective toward fulfillment of degree requirements, be required for admission into a profession program, or be required as part of graduate or professional program curricula. At some undergraduate institutions, both human anatomy and comparative vertebrate anatomy are offered as separate courses within the same academic department.

The laboratory portion of anatomy courses is traditionally focused on dissection of preserved animal cadavers and examination of mounted skeletons and/or anatomical models. Models and skeletons used in these laboratories are quite expensive; for example, recent list prices from a biological supply catalog for a single mounted carp (fish) and dog skeleton were \$579.00 and \$939.00 respectively. Skulls are slightly less costly; the same catalog listed a rabbit skull at \$215.00 and a cow skull at \$562.00. The costs of procuring non-expendable specimens for a new course can be beyond budget limitations. For example, the purchase of seven rabbit skulls for a class with an enrollment of fourteen students (one skull per pair of students) would require an initial investment of \$1,505.00, excluding shipping costs. For labs featuring dissection, additional costs are associated with the use of preserved cadavers. Not only is there a cost to purchase and store the cadavers for the term, but also a significant cost for disposal. With strained course budgets, anatomy instructors may be faced with the decision of whether or not to replace old models or even include dissection as part of the curriculum (Winkelmann, 2007).

One alternative for reducing the use of preserved materials or models is computer-aided learning

(CAL) (Paalman, 2000). The use of CAL ranges widely from teaching human reproductive anatomy to elementary school students (Dalton et al., 1989), to teaching basic veterinary anatomy (Khalil et al., 2005) and complex segmental liver anatomy for radiology residents (Kuszyk et al., 1997). In addition to reducing the costs of materials, CAL provides instructors greater flexibility in dissemination of material and students with increased opportunities for learning (Paalman, 2000). Computer-aided learning appears to be as effective as traditional dissection in learning anatomy (Bukowski, 2002; Khalil et al., 2010; Hopkins et al., 2011). In some cases, CAL used with traditional methods has produced positive learning outcomes (Elizondo-Omaña et al. 2004). McNulty and colleagues (2004) found that as use of CAL increased so did medical students' anatomy exam scores. Studies also report that students readily and positively accept CAL (Allen et al., 2008; Khalil et al., 2010).

I was faced with reinstating a comparative vertebrate anatomy course which had not been taught at my institution for more than ten years. Because of a limited budget for course supplies, incorporating CAL modules into the laboratory portion of the course became a viable alternative to purchasing a number of models and skeletons. Unfortunately, software featuring 3D interactive images can be expensive and writing code to generate complex programs can require specialized skills and equipment (Petersson et al., 2009). To avoid extra costs and using a modest programming skill set, I created a series of web-based interactive modules for the study of mammalian skull anatomy using skulls already on hand, an open source image editor, and a text editor. The modules featured pointer-over identification of bones and bony landmarks with

color delineation of the borders of targeted bones and landmarks. An accompanying label identifying the targeted item was also highlighted when the pointer moved over it. By housing the modules on our institution's learning management system (LMS) (Jenzabar v. 7.4.2), students had instant access to the images and accompanying practice quizzes whenever they wished.

METHODS

Creation of each module required three separate steps: the photography and image touch-up, the image mapping and HTML (Hyper Text Markup Language) code generation, and finally, writing the JavaScript functions that do the actual real-time user interaction. HTML image mapping with JavaScript was selected for the following reasons: it has better cross-platform (Windows/Mac/Linux/Unix/other) compatibility, better low-bandwidth performance than Flash or specialty CGI (computer-generated imagery) coding, easier integration with existing server software and LMS engines, few browser or Flash version compatibility issues, and it requires minimal web coding.

An Olympus E-500 8.0 megapixel digital camera with an Olympus 14 - 45 mm lens was used to photograph the individual skulls featured in the modules. With a square yard of black broadcloth serving as a background, each specimen was positioned on a one quart bag of sand placed under the cloth. In addition to the camera's flash, a fluorescent shop light and goose neck LED desk lamp provided back lighting. Skulls were photographed in separate frontal, dorsal, ventral, and lateral views. The initial images were saved in .tiff format at 3264 x 2448 pixels per inch resolution.

Image maps delineating the borders of individual bones and bony landmarks within the images were created using the GNU Image Manipulation Program v. 2.6 (GIMP) (<http://gimp.org>, 2011) for Linux operating systems. GIMP is an open source program for image composition, photo retouching, and other types of image manipulations. The program will also run on Microsoft Windows and Mac OS X. I found the program to be very user friendly and well supported by tutorials and user group blogs.

Image mapping of individual bones and landmarks within an image can be easily accomplished using the steps I followed. First, the image was cropped using the auto crop function
 <Image> -> Autocrop Image -> Edit -> Copy -> Edit -> Paste as -> New Image
 then scaled to 640 x 480 pixels at 72 pixels per inch resolution using the scale image function
 <Image> -> Scale Image
 in order to fit the viewing area of the LMS. The cropped image was saved in .png format for browser compatibility. I next selected the Web Image Map tool under Filters in the main toolbar

<Filters> -> Web -> Image Map
 and using the polygon or circle selection, defined the area of an individual bone or landmark by tracing its boundaries or changing the size and position of the circle. GIMP automatically generated the associated HTML code defining the map. The following is a simplified example for a polygon drawn over a bone:

```
<map name="mymap">
  <area shape="poly"
  coords="202,240,250,238,273,350,193,313">
</map>
```

Note that the map tag <map> ...</map> encapsulates an "area" tag. It is the area tag that defines the size and shape of a portion of the target image, that is, the specific bone or bony landmark. The comma-separated decimal values in the "coords" property are x,y pixel coordinates of angle points for the polygon. Put simply, the x,y coordinates are the "dots to be connected" in drawing the polygon. There may be multiple area tags for each image, as there were in the skull images.

Each resulting set of area coordinates was identified in the Area Settings screen with the appropriate name of the bone or landmark mapped before mapping the next item in the image. The final image map containing multiple area coordinates was saved with a .map extension (Figure 1) (See Appendix 1 for the GIMP HTML snippet for Figure 1).

The next step in the process was to create a web page featuring the image and an accompanying legend with the name of each bone or bony landmark to be identified. I used a plain text editor to code the web page, but any standard web-page creation tool (e.g. Microsoft® Office FrontPage®) would work as well. The HTML in the .map file was copied and pasted into the web page HTML code following the image tag that was modified to include a "usemap" property referencing the name of the skull image map (see Appendix 2).

HTML image map area tags support a variety of JavaScript functions that allow user interactivity. In this case, when the cursor is moved into the target



Fig 1. Example of image-mapped bones and bony landmarks generated by the image mapping function of the Gnu Image Manipulation Program (GIMP) on a coyote skull.

area, the legend color of the target bone or bony landmark changes from green to yellow. The following functions were used in the modules:

OnMouseOver() – The mouse pointer is over a section of a particular mapped segment.

OnMouseOut() – The mouse pointer has moved off the mapped segment previously reported.

OnClick() – The mouse button has been clicked indicating a selection.

The color of the text that changes is controlled by a style segment written in CSS (cascading style sheet) format. The style segment defines divisions (<div></div>) or “chunks” of the web page and defines each particular division’s general display attributes. A separate division was defined for each legend line that can control the display attributes, such as text color, for each legend line individually. Three similar JavaScript action functions were written to manipulate colors of the text descriptions of the mapped areas. This is an example of the “ramus” polygon area of Figure 1 modified to include three JavaScript action functions:

```
<area shape="poly"
coords="202,240,250,238,273,350,193,313"
alt="ramus"
onMouseOver="makeYellow('text1')"
onClick="makeGreen('text1')"
onMouseOut="restoreColor('text1')"
/>
```

The addition of this code in each of the area tags is identical except for the designation of the bone name representing the mapped segment of the image (See Appendix 2). This method allowed me to not only create a multi-area mapped image but to use a single area for object level flexibility. The resulting web page was integrated into the LMS portal for the course.

I created online practice quizzes within our LMS portal using its Test Builder function. The quizzes consisted of 20 multiple choice questions based on the four image views of each skull, reusing the mapped areas previously defined for the study



Fig. 2. Example of an online practice quiz question to identify a bony landmark. Color delineation of the ramus was generated using the image mapping function of the Gnu Image Manipulation Program (GIMP).

modules. Individual questions featured one of the images with a specific area highlighted to be identified (Figure 2). The mouse-related functions were not used in quiz questions.

Students were given each of the skulls featured in the modules and a laptop computer to access the images during laboratory. They were allowed to work at their own pace for up to one hour of the laboratory period. In order to encourage them to use the module and quizzes for study, students received a handout containing instructions on how to access the materials (a copy of the handout may be requested by emailing the author). Practice quizzes were allotted a 10 minute completion time but allowed unlimited attempts.

RESULTS

I made a preliminary assessment of the modules using practical exam scores for questions based on each skull, LMS usage statistics, and our standard student course evaluations. The skull modules consisted of 12 area-mapped images of three mammal skulls (coyote, deer, and human) in four orientations. Once familiar with the steps required, I was able to complete an image with up to 20 mapped bones or landmarks and create the associated web page in less than four hours. A demonstration of one of the modules is available at: <http://facultyweb.berry.edu/rcarleton/skulldemo>.

Student use of the modules outside of laboratory varied. Five of the six students enrolled in the course accessed the study modules an average of 6.2 times (range 1 to 18 times). Four students accessed one or more module quizzes prior to the midterm exam. The amount of time students spent on quizzes and number of quiz attempts varied by skull type and by student. Quiz scores ranged from 11 of 20 correct (55.0%) to 20 of 20 correct (100.0%) depending on skull type and number of attempts. One student, who did not access the modules or quizzes outside of lab, missed five of the six questions pertaining to skull anatomy on the midterm examination; all other students answered the questions correctly. Each of the four students who completed the online course evaluation included positive comments about the modules.

DISCUSSION

Computer-aided learning can be easily incorporated into an anatomy course using good quality digital photography, an open source image editor, a fairly basic set of programming skills, and a little innovation. Creating my own CAL modules allowed me to customize the software to my course curriculum and to the specimens I had on hand. It also allowed me to work within my course budget by negating the need to purchase expensive materials and commercially-available software. Although not enough data were available to analyze learning

outcomes, it was determined that most of the students enrolled in the course voluntarily used the modules for study and generally did well on exam questions. Although it may seem daunting to develop CAL tools, I found it relatively easy, requiring minimal assistance, and well worth the effort.

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APPENDIX 1

Example of HTML code generated by the GIMP image mapping function to define bones and bony landmarks of the coyote skull featured in Figure 1.

```
<map name="mymap">
<!-- #$.:Image map file created by GIMP Image Map plug-in -->
<!-- #$.:GIMP Image Map plug-in by Maurits Rijk -->
<!-- #$.:Please do not edit lines starting with "$" -->
<!-- #$.VERSION:2.3 -->
<!-- #$.AUTHOR:Renee Carleton -->
<area shape="poly" coords="202,240,250,238,273,350,193,313" alt="ramus" />
<area shape="poly" coords="84,270,131,292,128,306,80,300" alt="tympanic bulla" />
<area shape="poly" coords="26,270,61,235,73,242,45,299" alt="occipital condyle" />
<area shape="poly" coords="24,122,86,84,89,109,34,143" alt="sagittal crest" />
<area shape="poly" coords="298,349,508,362,501,392,387,411,280,400" alt="body of mandible" />
<area shape="poly" coords="394,187,524,216,548,273,345,298" alt="maxillary" />
<area shape="circle" coords="105,260,14" alt="external acoustic meatus" />
<area shape="poly" coords="84,202,168,183,164,238,128,245,88,230" alt="squamosal" />
<area shape="poly" coords="305,193,366,219,340,281,313,262,273,183,282,177" alt="jugal" />
<area shape="poly" coords="179,189,265,178,271,207,206,206,176,218" alt="zygomatic arch" />
<area shape="poly" coords="236,95,282,97,393,171,372,210,250,153" alt="frontal" />
<area shape="poly" coords="543,228,567,276,598,283,556,231" alt="premaxilla" />
<area shape="poly" coords="105,104,226,99,244,169,85,190,66,140" alt="parietal" />
</map>
```


APPENDIX 2

Complete web page code to generate interactive mouse action identification of individual bones and bony landmarks of the coyote skull featured in Figure 1.

```
<html>
<head>
<script language="javascript" type="text/javascript">
function makeGreen(object) {
document.getElementById(object).style.color = "green";
}
function makeYellow(object) {
if (document.getElementById(object).style.color == "green") {
document.getElementById(object).style.color = "orange";
} else {
document.getElementById(object).style.color = "yellow";
}
}
function makeWhite(object) {
document.getElementById(object).style.color = "white";
}
function restoreColor(object) {
if (document.getElementById(object).style.color != "green") {
if (document.getElementById(object).style.color == "orange") {
document.getElementById(object).style.color = "green";
} else {
document.getElementById(object).style.color = "white";
}
}
}
function resetAll() {
for (i=1; i < 25; i++) {
var obj = "text" + i;
makeWhite(obj);
}
}
</script>
<style type="text/css">
div#main
{ width: 780px;
height: 675px;
margin-top: 0;
margin-left: 0;
margin-right: 0;
margin-bottom: 0;
padding: 0;
background-color: black;
overflow: hidden;
}
div#image
{ width: 640px;
height: 480px;
float: right;
margin-top: 0;
margin-left: 0;
margin-right: 0;
margin-bottom: 0;
padding: 0;
overflow: hidden;
}
div#label
{ position: absolute;
top: 0;
left: 0;
width: 155px;
margin-bottom: 0;
margin-left: 0;
margin-right: 0;
margin-top: 0;
padding: 0;
}
div#text0,div#text1,div#text2,div#text3,div#text4,div#text5,div#text6,div#text7,div#text8,
div#text9,div#text10,div#text11,div#text12,div#text13
{ font-family: arial;
font-size: 13px;
font-weight: bold;
```

```

color: white;
margin-left: 3px;
margin-top: 1px;
margin-bottom: 1px;
margin-right: 0;
width: 160px;
float: left;
}
</style>
<title>Coyote Skull -- Lateral View</title>
</head>
<body bgcolor=black>
<div id="main">
<div id="image">
<map name="map2">
<!-- for coyote_skull_lateral -->
<!-- #$.:Image map file created by GIMP Image Map plug-in -->
<!-- #$.:GIMP Image Map plug-in by Maurits Rijk -->
<!-- #$.:Please do not edit lines starting with "#$" -->
<!-- #$.VERSION:2.3 -->
<!-- #$.AUTHOR:Renee Carleton -->
<!-- Coyote Skull Lateral -->
<area id="csl1" shape="poly" coords="202,240,250,238,273,350,193,313" alt="ramus" onMouseOver="makeYellow('text1')" onClick="makeGreen('text1')"
onMouseOut="restoreColor('text1')" />
<area id="csl2" shape="poly" coords="84,270,131,292,128,306,80,300" alt="tympanic bulla" onMouseOver="makeYellow('text2')"
onClick="makeGreen('text2')" onMouseOut="restoreColor('text2')" />
<area id="csl3" shape="poly" coords="26,270,61,235,73,242,45,299" alt="occipital condyle" onMouseOver="makeYellow('text3')"
onClick="makeGreen('text3')" onMouseOut="restoreColor('text3')" />
<area id="csl4" shape="poly" coords="24,122,86,84,89,109,34,143" alt="sagittal crest" onMouseOver="makeYellow('text4')"
onClick="makeGreen('text4')" onMouseOut="restoreColor('text4')" />
<area id="csl5" shape="poly" coords="298,349,508,362,501,392,387,411,280,400" alt="body of mandible" onMouseOver="makeYellow('text5')"
onClick="makeGreen('text5')" onMouseOut="restoreColor('text5')" />
<area id="csl6" shape="poly" coords="394,187,524,216,548,273,345,298" alt="maxillary" onMouseOver="makeYellow('text6')"
onClick="makeGreen('text6')" onMouseOut="restoreColor('text6')" />
<area id="csl7" shape="circle" coords="105,260,14" alt="external acoustic meatus" onMouseOver="makeYellow('text7')" onClick="makeGreen('text7')"
onMouseOut="restoreColor('text7')" />
<area id="csl8" shape="poly" coords="84,202,168,183,164,238,128,245,88,230" alt="squamosal" onMouseOver="makeYellow('text8')"
onClick="makeGreen('text8')" onMouseOut="restoreColor('text8')" />
<area id="csl9" shape="poly" coords="305,193,366,219,340,281,313,262,273,183,282,177" alt="jugal" onMouseOver="makeYellow('text9')"
onClick="makeGreen('text9')" onMouseOut="restoreColor('text9')" />
<area id="csl10" shape="poly" coords="179,189,265,178,271,207,206,206,176,218" alt="zygomatic arch" onMouseOver="makeYellow('text10')"
onClick="makeGreen('text10')" onMouseOut="restoreColor('text10')" />
<area id="csl11" shape="poly" coords="236,95,282,97,393,171,372,210,250,153" alt="frontal" onMouseOver="makeYellow('text11')"
onClick="makeGreen('text11')" onMouseOut="restoreColor('text11')" />
<area id="csl12" shape="poly" coords="543,228,567,276,598,283,556,231" alt="premaxilla" onMouseOver="makeYellow('text12')"
onClick="makeGreen('text12')" onMouseOut="restoreColor('text12')" />
<area id="csl13" shape="poly" coords="105,104,226,99,244,169,85,190,66,140" alt="parietal" onMouseOver="makeYellow('text13')"
onClick="makeGreen('text13')" onMouseOut="restoreColor('text13')" />
</map>

</div>
<div id="label">
<br><br>
<div id=text1>&bull; Ramus</div>
<div id=text2>&bull; Tympanic Bulla</div>
<div id=text3>&bull; Occipital Condyle</div>
<div id=text4>&bull; Sagittal Crest</div>
<div id=text5>&bull; Body of Mandible</div>
<div id=text6>&bull; Maxillary</div>
<div id=text7>&bull; External Acoustic Meatus</div>
<div id=text8>&bull; Squamosal</div>
<div id=text9>&bull; Jugal Bone</div>
<div id=text10>&bull; Zygomatic Arch</div>
<div id=text11>&bull; Frontal</div>
<div id=text12>&bull; Premaxilla</div>
<div id=text13>&bull; Parietal</div>
</div>
<div id="button" onLoad="resetAll()">
<input type="button" name="Reset" value="Reset Colors" onClick="resetAll()">
<br><br>
</div>
</div>
</body>
</html>

```

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