

VISUALIZATION OF CANINE GAIT USING OPTICAL MOTION CAPTURE  
ANIMATION: A STUDY OF ITS EFFECTIVENESS AT HELPING STUDENTS  
IDENTIFY LAMENESS

A Non-Thesis

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By

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## CHAPTER 1

### INTRODUCTION

As technology changes, ways of viewing motion evolves. Perhaps the first ways of portraying sequential motion of objects were etchings in earth or rock, or paintings on cave walls, much like those found in the caves of Lascaux, France. The Egyptians portrayed sequences of events by paintings on tomb and temple walls. These representations were events separated by more than seconds or moments in time.

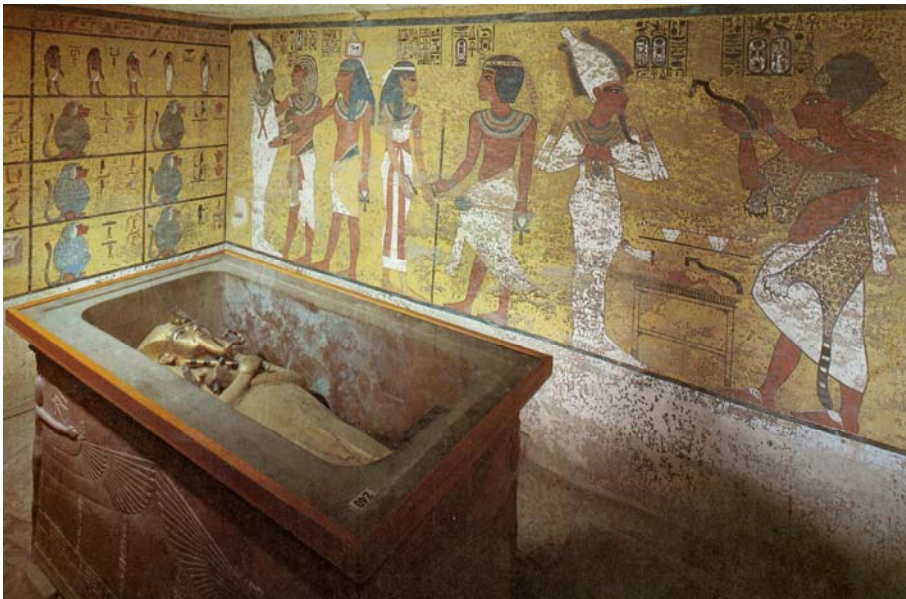


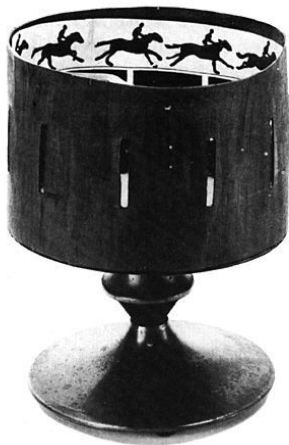
Figure 1. The transfer of power from Pharaoh Tutankhamun, seen wrapped in white linen from head to foot, to Ay, dressed in leopard skin. Read from right to left. Middle image

depicts the goddess Nut greeting the deceased pharaoh. The far left depicts the new pharaoh, Ay, embracing the god Osiris. Illustration taken from Peoples and Places of the Past, copyright 1983, published by the National Geographic Society.



In 1834, William George Horner invented the “Daedalum” or “Wheel of the Devil.” It was a rotating drum that contained a strip of paper on which sequential images were drawn. The drum had slits in the top of it to view the images inside. When rotated, a character or object appeared to move.

Figure 2. Above is the “Daedalum” invented by William George Horner. The picture is taken from <http://www.illuweb.it/cinema/cinezoot.htm>



Approximately 30 years later, in 1868, William Lincoln applies for a patent for the “Zoetrope” which was the same design as the daedalum

Figure 3. To the left is an example of a Zoetrope. Inside are paintings of a horse and rider in motion. The picture is taken from

<http://www.manovich.net/Vertov/Zoetrope.JPG>

The “Flip Book” or kineograph was patented in 1868, by John Barnes Linnett, with the beginnings of animation, photography and cinema. Flip books have sequential drawings or photographs bound in a single book. When thumbed through rapidly, the images give the illusion of continuous sequential movement of a character over a brief period in time. Flip books were used as novelties or toys and then as marketing tools.

(Reference: <http://www.flippies.com/history.htm>)



Figure 4. Above is a cover of a flip book used by McDonalds for advertising. Picture is from <http://www.flippies.com/history.htm>

The photographic process of developing a negative that could be reprinted many times developed in the mid 1800s. It was around this time that Eadweard Muybridge, a pioneer of motion studies and an inventor of the camera shutter, began photographing people and non-human animals with multiple cameras firing in sequence. In 1873, he was commissioned to photograph a horse in motion. The shutter speeds he used were 1/1000<sup>th</sup> of a second. The images caught, proved that there is a period in time during a horses' gallop, when all four feet are off the ground at once. Many people thought he retouched

his negatives to create the effect. Until this time, people believed that a horse always had a foot on the ground at all times.

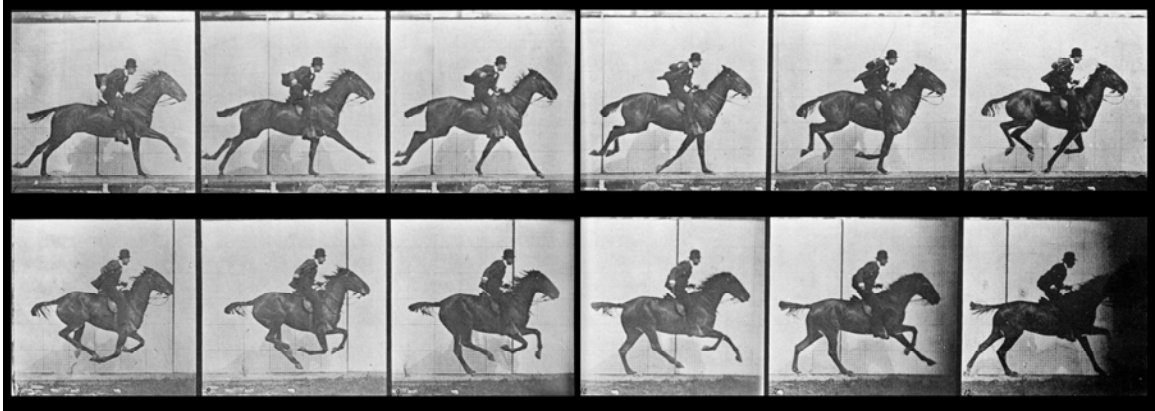


Figure 5. Above is a photographic sequence of a horse named Daisy galloping, taken by Eadweard Muybridge. The image came from “Animals in Motion” by Eadweard Muybridge, plate 67.

Video and cinema are essentially the same as looking at sequential photographs, one at a time, through the zoetrope. The exception being that now we look at images projected on a screen rather than the inside of a drum.

VRML, Virtual Reality Markup Language, emerged in the mid 1990s from a collection of people around the world interested in bringing 3-D experience to the web. The standard originally came from Silicon Graphics Open Inventor format. Various plugins exist today to view VRML files on the web. Cortona, by Parallel Graphics is a popular one. VRML allows a user to rotate about an object in space or navigate, i.e. walk or fly, through a 3-D environment. The objects or environments can be built in a 3-D

computer graphics program such as Alias Maya. Lights and different camera view points can be included in the VRML files. Animated objects can be exported to VRML, but Cortona does not offer the user the ability to stop and start the animation sequence.

Optical motion capture involves the recording of reflected light from small markers attached to a moving person or non-human animal. A computer records the position of the markers in space. An animator can then use the marker positions in software such as MotionBuilder 6 and Alias Maya 6 to build character animation skeletons that move within the markers. 3-D models can be bound to the animation skeleton and rendered to produce animated motion capture sequences, or exported to a VRML file for viewing with Cortona. Motion capture can produce very realistic animal motion. However, if the data is manipulated too much, the motion will lose its similarity to the original motion.

Through the history of art, visual communication, and computer graphics there has been a trend toward more realistic representation of three-dimensional space. The purpose of my study is to assess student preference for visuals used to teach about motion and to see how effective motion capture animation is at helping veterinary students identify lameness in dogs. Though my application of the technology was with veterinary medical students identifying lameness, it could have been applied to other examples as well. Similar applications could be using motion capture animation to teach students dance steps or karate moves. It could also be used to help physical therapy students visualize gait problems in humans. Some companies use motion capture to improve golfers' swings.

ISeeSoft, a Cincinnati based company, used optical motion capture to create a program called "World Dance." They designed the application to teach people dance steps from all around the world. ISeeSoft is currently working on collecting martial art moves. Their final output is an interactive 3-D figure performing the moves, which you can navigate around through the Shockwave interface, much like the VRML output I have created with the dog data. Examples of their work can be found at [www.iseesoft.com](http://www.iseesoft.com).

## CHAPTER 2

### METHODS

My first step was to create a learning module for the veterinary students. The learning module contained both video and motion capture of dogs with normal gait, hip dysplastic gait, and cranial cruciate ligament rupture. The students had several fixed view points to choose between. They were “side”, “overhead”, “frontal”, and “posterior”. With the videos, the view points were mostly “side” and a combined “frontal/posterior”. I had no “overhead” views within the video recordings of the dogs. The students also had the choice to see the dogs “walking”, “trotting”, and climbing “stairs”. The navigation system was global rather than linear. The students had the option to jump from one condition to another, from one view point to another, or from walking to trotting or stair climbing. The learning module had text descriptions on every scene. They described the foot fall sequence for the walking, trotting, and stair climbing. The text also described characteristics to look for in dogs with the particular condition. For example, a dog with a cranial cruciate ligament rupture will have more flexion in the good stifle (knee) joint than in the injured stifle. I narrated the text. The student could turn the narration on and off by clicking on buttons. Altogether, there were 69 scenes in the Flash file in which I put the final learning module together.

After I created the learning module, I wrote a survey and a quiz. The quiz contained “unknown” examples of dogs with normal gait, hip dysplastic gait, and cranial cruciate ligament rupture. I divided the quiz into 5 videos and 5 motion capture examples. After viewing the animation or video, I asked the student to identify which leg or legs were lame, or if the dog had normal healthy gait. The survey mainly had questions about the usability of the learning module and then questions about visual preference. All three, the Canine Lameness Learning Module, the quiz, and the survey were internet based. I did, however, burn over 350 copies of the learning module on CD-ROM and put them in student mailboxes. They were mainly for students who wanted to view the learning module on a computer that had a slow internet connection. The CD-ROMs were a huge waste of my money and time due to the very few number of students that participated.

Paul Rand once compared design to ditch digging. When I began my project, I never thought my ditch would be so long, or that I would encounter so many large chunks of granite in the process. The technical challenges of this project were great. The following is a list that summarizes the problems I encountered.

1. I had trouble getting the optical motion capture markers to stay on the dogs. They would shake them off. After I struggled with one dog that had a particularly oily coat, I searched for suits for dogs that I could sew Velcro patches to. I purchased two black lycra zip-up dog suits through K-9 top coat ([http://www.k9topcoat.com/pilot.asp?pg=testimonials\\_home](http://www.k9topcoat.com/pilot.asp?pg=testimonials_home)).

2. When I captured the dogs, there was occlusion of reflected light from their markers because someone had to lead them across the capture floor during recording.
3. There were sets of markers that continually swapped identities throughout the capture sessions. These were the two markers to the sides of the ankles and wrists, the two markers on the front and side of the stifle (knee), and the sacral and top of tail markers.
4. The occlusion of light led to large gaps in the data. These gaps had to be hand key-framed to make up for missing marker data.
5. The software used for the second stage of cleaning, MotionBuilder 5.5, would not create a quadruped animation skeleton that would follow the dog marker data with accuracy. The technical support simply told me that I was trying to do something with the software that it wasn't made to do. I ended up with a skeleton that looked like a giraffe when it moved.
6. The next step involved a lot of experimenting in Maya with rigging until I found a method that worked.

## THE PROCESS OF COLLECTING THE DATA FOR THE LEARNING MODULE FROM THE VERY BEGINNING.

I motion captured six dogs. These were dogs belonging to friends and work associates. I designed a marker placement that was similar to that used on the human body. See the figure below for the marker placement. My marker set contained 49

markers that were ~24mm diameter. A shiny silver reflective material (Scotch Brite) much like that found on jogging shoes covered the markers.

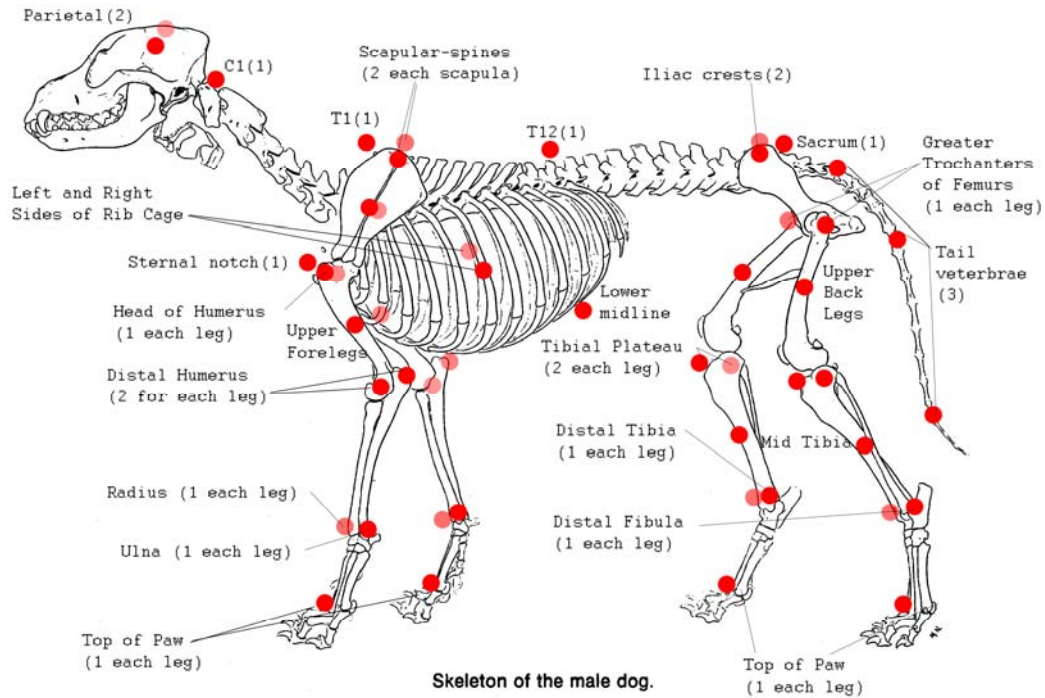


Figure 6. Skeleton of a male dog showing the location of the optical motion capture markers.

The optical motion capture system used to record the dogs was a Vicon 8. There were 12-14 cameras. The capture space was approximately a square area with a 17 foot long diagonal. A person, usually me, led the dogs across the diagonal of the space while another operated the capture software. Below is the marker file I used with the application Vicon Workstation in order to label the dog markers.

```

!MKR#2
[Autolabel]
LFHD Left front head
RFHD Right front head

```

|      |                          |
|------|--------------------------|
| C1   | Base of skull            |
| T1   | Base of neck             |
| T12  | Curve of back            |
| MANU | Manubrium                |
| RIBS | Base of rib cage         |
| LRIB | Left side of ribs        |
| RRIB | Right side of ribs       |
| LSCP | Left scapula             |
| LMSP | Left mid scapula         |
| LHHD | Left humeral head        |
| LUPF | Left upper foreleg       |
| LFEL | Left front elbow         |
| LSEL | Left side elbow          |
| LPSA | Left pastern inner side  |
| LPSB | Left pastern outer side  |
| LFPW | Left front paw           |
| RSCP | Right scapula            |
| RMSP | Right mid scapula        |
| RHHD | Right humeral head       |
| RUPF | Right upper foreleg      |
| RFEL | Right front elbow        |
| RSEL | Right side elbow         |
| RPSA | Right pastern inner side |
| RPSB | Right pastern outer side |
| RFPW | Right front paw          |
| SAC  | Sacrum                   |
| LILC | Left iliac               |
| RILC | Right iliac              |
| LFD  | Left femoral head        |
| LUPB | Left upper back leg      |
| LFSF | Left front stifle        |
| LSSF | Left side stifle         |
| LMTB | Left mid tibia           |
| LHCA | Left hock inner side     |
| LHCB | Left hock outer side     |
| LBPW | Left back paw            |
| RFD  | Right femoral head       |
| RUPB | Right upper back leg     |
| RFSF | Right front stifle       |
| RSSF | Right side stifle        |
| RMTB | Right mid tibia          |
| RHCA | Right hock inner side    |
| RHCB | Right hock outer side    |
| RBPW | Right back paw           |
| PTAL | Proximal tail            |
| MTAL | Middle tail              |
| DTAL | Distal tail              |

Head = LFHD, RFHD, C1  
Root = T1, T12, MANU, RIBS, LRIB, RRIB

LeftScapula = LSCP, LMSP, LHHD  
LeftUpperForeLeg = LHHD, LUPF, LFEL, LSEL  
LeftLowerForeLeg = LFEL, LSEL, LPSA, LPSB  
LeftFrontPaw = LPSA, LPSB, LFPW

RightScapula = RSCP, RMSP, RHHD  
RightUpperForeLeg = RHHD, RUPF, RFEL, RSEL  
RightLowerForeLeg = RFEL, RSEL, RPSA, RPSB  
RightFrontPaw = RPSA, RPSB, RFPW

Pelvis = SAC, LILC, RILC

LeftUpperBackLeg = LFD, LUPB, LFSF, LSSF  
LeftLowerBackLeg = LFSF, LSSF, LMTB, LHCA, LHCB  
LeftBackPaw = LHCA, LHCB, LBPW

RightUpperBackLeg = RFD, RUPB, RFSF, RSSF  
RightLowerBackLeg = RFSF, RSSF, RMTB, RHCA, RHCB  
RightBackPaw = RHCA, RHCB, RBPW

Tail = SAC, PTAL, MTAL, DTAL

Head, Root  
Root, LeftScapula  
LeftScapula, LeftUpperForeLeg  
LeftUpperForeLeg, LeftLowerForeLeg  
LeftLowerForeLeg, LeftFrontPaw  
Root, RightScapula  
RightScapula, RightUpperForeLeg  
RightUpperForeLeg, RightLowerForeLeg  
RightLowerForeLeg, RightFrontPaw  
Root, Pelvis  
Pelvis, Tail  
Pelvis, LeftUpperBackLeg  
LeftUpperBackLeg, LeftLowerBackLeg  
LeftLowerBackLeg, LeftBackPaw  
Pelvis, RightUpperBackLeg  
RightUpperBackLeg, RightLowerBackLeg  
RightLowerBackLeg,  
RightBackPaw

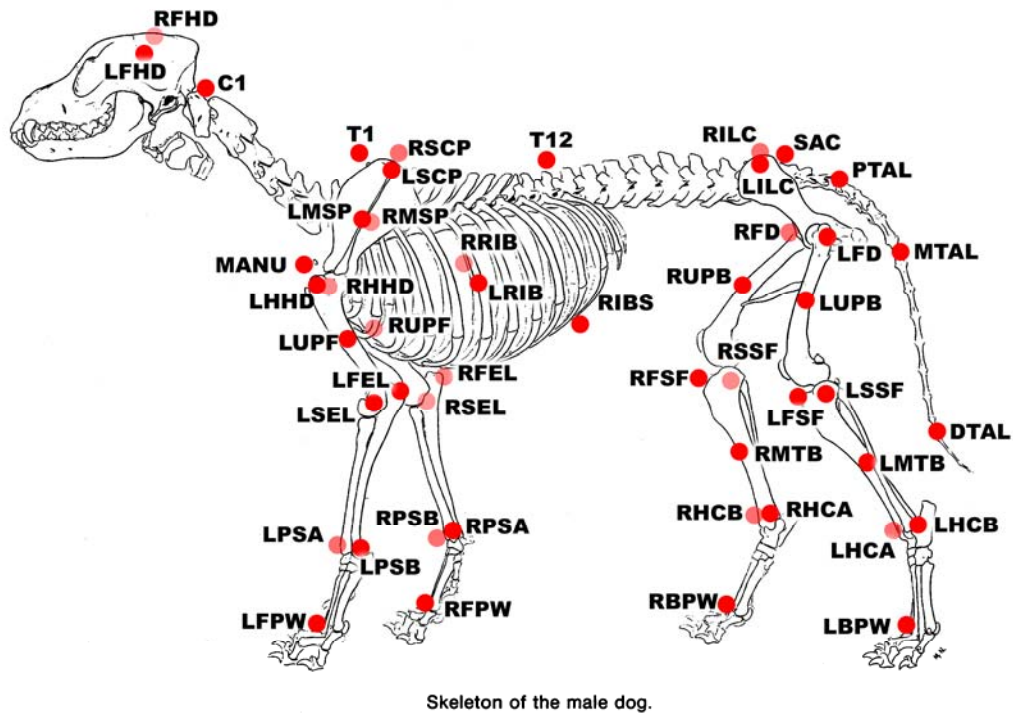


Figure 7. Above is a skeleton of a male dog with my marker labels.

I wrote the marker file above in Notepad and saved it as a .txt file. I later gave the file a .mkr extension in order to work with Workstation. In Workstation, I labeled the markers, fixed swaps in marker identities, filled very small gaps (10 frames), deleted spikes, deleted bad tail data at the ends of trajectories, deleted ghost markers, and joined fragmented trajectories. The markers that swapped identities every other frame were the following sets: RPSA & RPSB, LPSA & LPSB, RHCA & RHCB, LHCA & LHCB, and sometimes SAC & PTAL. I had to delete many ghost markers because I had Workstation reconstruct my motion capture files to show any trajectory that just one of the fourteen cameras picked up. Normally, you set the reconstruction to show trajectories that were seen by three cameras. I did this because I had so many gaps/occlusions in my data that I didn't want to lose any of it that was recorded. A ghost marker is a very short lived

marker that is a duplicate of another marker. A spike is when a marker suddenly jumps out of position and then back.

The second program I used was MotionBuilder 5 and then version 5.5. Kaydara made Motion Builder. Alias bought Kaydara in September of 2004. Though Kaydara advertised that they included the ability to animate a quadruped in MotionBuilder 5.5, that did not mean that it was made to work with quadruped motion capture data. Some people use MotionBuilder as their animation package. Kaydara simply included a quadruped character which could be rigged and hand keyframed within MotionBuilder. I could not get a skeleton created in MotionBuilder 5.5 to follow my dog data with accuracy. I sent my best attempt to Kaydara's technical support. They experimented with the settings and then wrote back. They said I was trying to do something with their program that it was not made to do.

So, I used MotionBuilder 5 and 5.5 primarily to fill gaps in my data. MotionBuilder offers several gap filling options that Workstation does not. MotionBuilder will attempt to reconstruct the gap in the marker trajectory based on its pattern before and after the gap. Sometimes this works, but usually not. Sometimes I would flatten out the curve within the gap area and then set keyframes where I felt the maker should be. This was very tedious and time consuming. One can also put a "control curve" on top of the automatically created curve that MotionBuilder puts in the gap. One would then set keyframes on this curve to adjust the underlying curve in certain spots. Sometimes this worked, sometimes it didn't. Mostly, I spent many hours hand keyframing where I felt the maker should be located. There were some markers I just could not get perfect in MotionBuilder. So, I had to set some keyframes on the markers in

Maya, which was the next program I used. I exported the cleaned marker data as .fbx files. I imported the .fbx into Alias Maya.

I used Maya to create a custom dog animation skeleton. I manipulated the skeleton to fit with each dog I motion captured. I created and bound 3-D polygonal models to the custom dog skeletons. I fitted the skeletons with RPik handles. I then point constrained the handles to the marker data. In this way, I was able to get a 3-D representation of the dogs to follow their respective motion capture data.

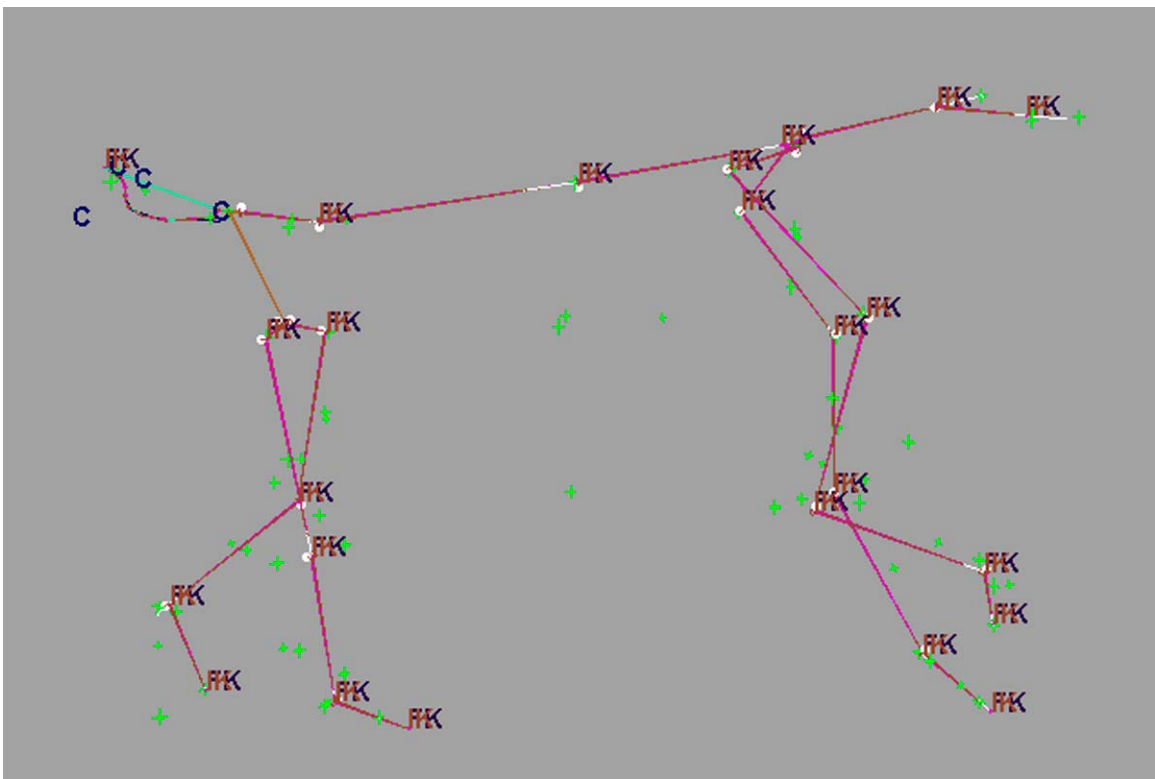


Figure .Above is a screen capture of the animation skeleton I built in Maya. The green crosses represent the markers. The IK symbols represent the spots where there are RPik handles on the bones of the skeleton.

I originally planned on binding realistic looking 3-D bone and muscle models to the animation skeletons. I wanted to show muscles contracting at various times in the gait

cycle. I went so far as to create a 3-D dog skeleton with individual bones. I managed to rig these bones to the dog skeleton that was constrained to the mocap data. It looked the best from the side. There were some unnatural looking movements to the bones from other perspectives. The spine in particular looked as if it was made of two separate rigid segments that made a sharp angle in the middle of the back when the dog moved its spine from side to side.

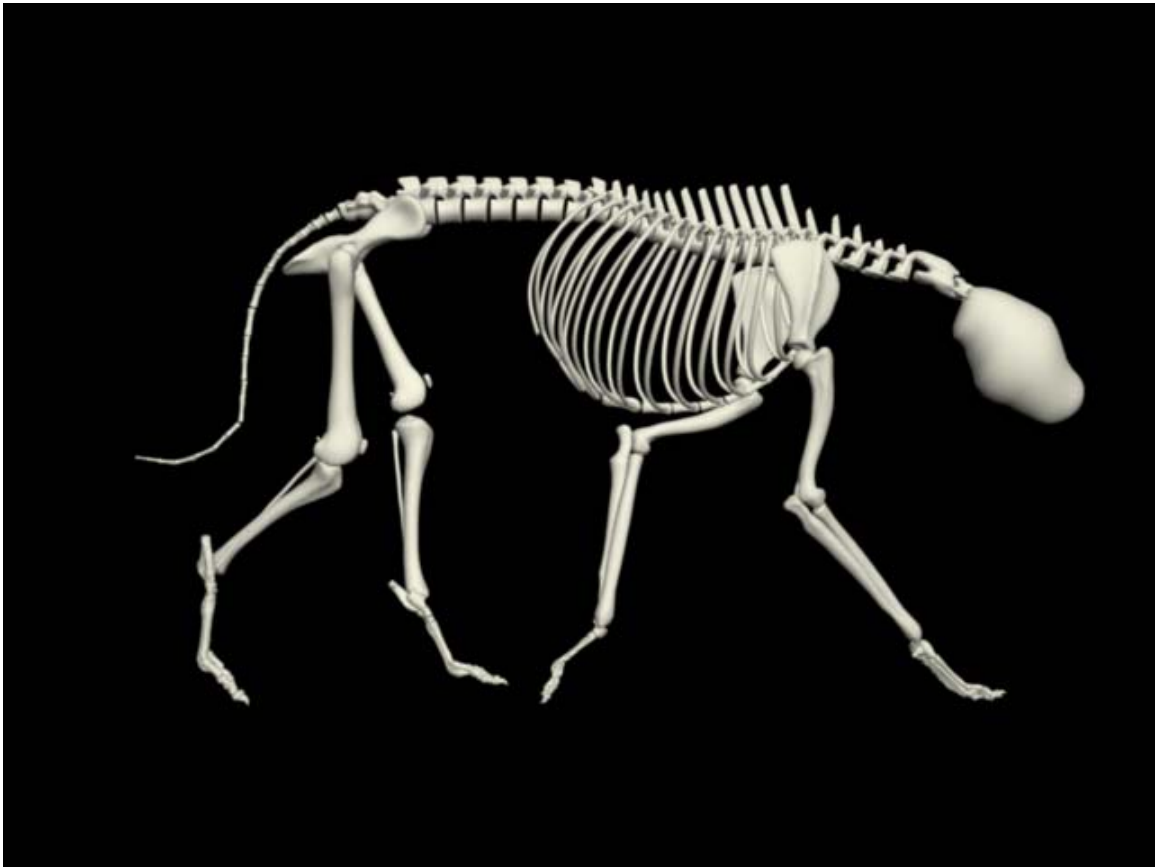


Figure . Above is an image of the bound 3-D dog skeleton that I modeled. It looks fairly good from the side. The toes are stiff because I was unable to attach a marker to the tips of the dogs toes during the motion capture session.

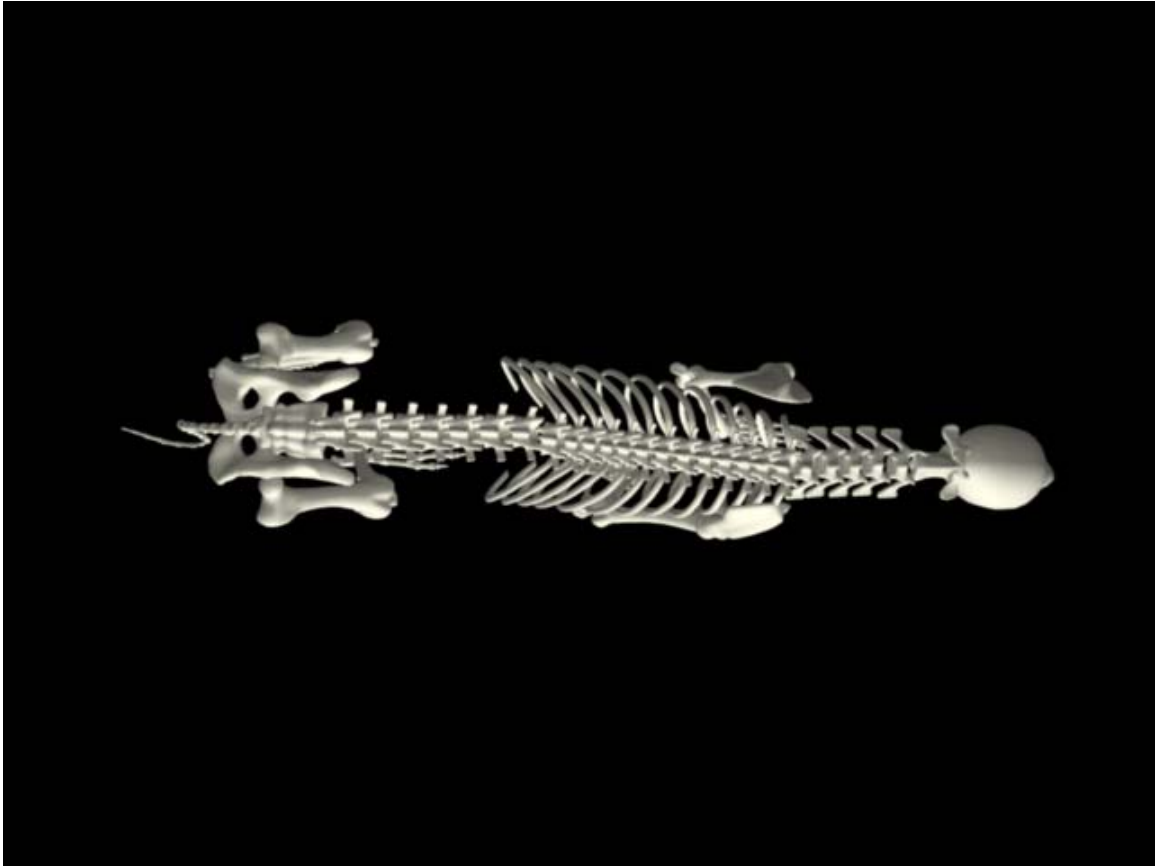


Figure . Above you see an overhead render of the rigged 3-D dog skeleton I created. Notice the middle of the spine. There is an unnatural kink in it. This was due to the fact that I only had one marker along the back between the neck and the pelvis and the fact that I had to use point constraints to rig the skeleton. The back of the animation skeleton is made up of two bones between the neck and pelvis. One runs from the base of the neck to the mid point of the back. The other runs from the mid point of the spine to the iliac crests of the pelvis. There is also an unnatural kink where the cervical (neck) vertebrae meet the thoracic vertebrae.

I eventually settled on an abstract representation of the dog made out of polygon cylinders for the bones. I used polygon cubes at the joints. I color coded the cubes. The right back leg was red. The left back leg was cyan. The right front leg was pink and the

left front leg was a lighter cyan. The spinal column, neck, head, and tail sections were blue. See the following figure to illustrate the abstract representation of the dogs.

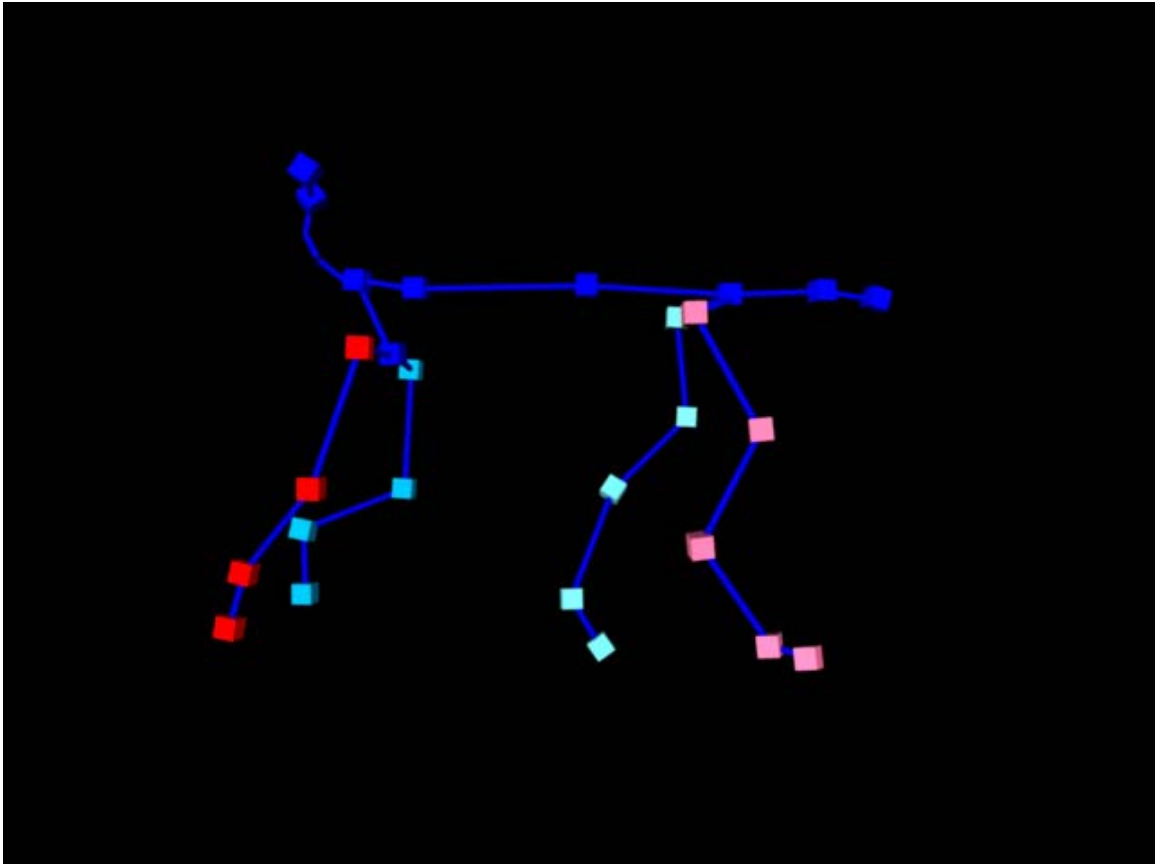


Figure . Above is the final abstract representation of the dogs that I used in the Canine Lameness Learning Module.

Cameras and lights were set up above the dog, to the sides of the dog, in front of the dog, and behind the dog in Maya. I chose start and end times for each dog animation that would make the animation appear to seamlessly loop. I then rendered each perspective (side, overhead, front, and posterior) as .tga (targa) files. The targa files were brought into Premiere 6 and exported as .mov files. I then used Sorenson Squeeze to compress and convert each animation to .flv files. FLV is Macromedia Flash's native video format. I then imported the .flv files into individual Flash movies for each

animation. I created buttons in Flash to allow the user to play, stop, play from the beginning, and go frame by frame through each animation/video.

I video taped the dogs that I motion captured plus several that I did not motion capture. I used a Canon GL-1 miniDV camera. I edited the video in Adobe Premiere Pro 7 and Premiere 6. I did not collect video of the overhead view, but I did collect the side, frontal, and posterior views. I exported the videos as .mov, compressed them, and converted them to .flv within Sorenson Squeeze.

There was one main Flash movie with 69 scenes. Each scene that had a video or motion capture animation contained an empty movie clip symbol. I used action script to load individual animations and videos into the empty movie clip symbols. In this way, I kept the file size of the main movie small and the learning module was able to load faster. I narrated each scene. The students had the option to turn the narration on and off by clicking on buttons in the Flash movie. The narration described the type of gait, e.g. walking, trotting, canter, or stair climbing. It also mentioned characteristics of normal gait, hip dysplastic gait, and cranial cruciate ligament rupture gait to look for.

I created a quiz for the students to take after they viewed the Canine Lameness Learning Module. The quiz was online. There were Flash swf files embedded in htm files. There were 5 videos and 5 motion capture animations of dogs with normal gait, hip dysplasia, or cranial cruciate ligament rupture. For the motion capture animations, I used the files I did not include in the Canine Lameness Learning Module so that they would be unknowns. These files were more subtle examples of lameness. I used the most obvious lameness animations in the learning module. In order to get unknowns for the videos, I video taped three dogs that were not in the learning module.

I created a survey to assess the usability of the learning module and student preference for visuals that teach about gait. I also included two matching questions within the survey that were more of a quiz-like nature. One question showed a video of a dog, and asked the student to identify which of three motion capture animations was the dog represented in the video. The other matching question was the reverse of the above. The survey was on-line. It consisted of htm files with swf files embedded and links to media requiring the Cortona plug-in. I used the following media for comparison when I asked for student preference: a VRML export of the greyhound with normal gait found in the learning module, a motion capture animation of the greyhound with normal gait trotting from the side perspective, a video of the greyhound with normal gait trotting from the side perspective, sequential photographs of a greyhound with normal gait galloping from the side perspective, and a diagram of footfall pattern for normal canter.

## APPENDIX A

### Survey of Visual Preferences for Learning about Canine Gait

The purpose of this survey is to assess student preference for visuals that teach about gait. It will assess how helpful motion capture vs. video is for learning about gait. You will be presented with three pages of questions. It should take approximately 20-30 minutes. Please answer them and then hit the submit button. The submit button will take you to the next page in the survey. You may quit at anytime without penalty. If you run out of time to finish, you may come back to the survey and skip to the question that you left off on, or bookmark it in your browser. Completion of this quiz is voluntary. By submitting your answers, you agree to their use in this research project. If you have any questions about the survey, you can contact Heather Caprette at [caprette.41@osu.edu](mailto:caprette.41@osu.edu) or Jonathan Dyce, D.V.M. at 292-3551.

1. If you took the Canine Lameness Learning Module, did you find the video or motion capture animation more helpful in regards to identifying a lame leg? Or did you prefer to have both to study from?
2. What did you find to be the advantages and disadvantages of each medium: video and motion capture animation. Please explain:
3. Which perspective/s did you find most helpful in identifying a lame hind leg? The perspectives were: side, overhead, frontal and posterior.

4. You can use the space below for any comments about the perspectives:

Below you will find the second page of the survey.

1. How easy was it to become familiar with the Canine Lameness Learning Module?

The options were: Very Easy, Easy, Somewhat Easy, Difficult, Very Difficult

2. The Canine Lameness Learning Module always did what I expected it to.

The options were: True, False

3. I enjoyed using the Canine Lameness Learning Module.

The options were: True, False

4. I understood what each selection did simply by reading the label on the tabs and buttons.

The options were: True, False

5. The instructions provided with the Canine Lameness Learning Module were easy to understand.

The options were: True, False

6. The information presented in the Canine Lameness Learning Module was clear and easy to understand.

The options were: Always, Most of the time, Half of the time, Less than half of the time, Never

7. Comments: Please use the box below to elaborate on any of the above answers or make any comments about the Canine Lameness Learning Module:

8. Followup: If you would be willing to answer any followup questions in regards to this study, please enter your email address below:

Below is page three of the survey.

### Survey of Visual Preferences for Learning about Canine Gait

Please view the following examples of visuals used to teach about gait and then rank them in order of preference. The examples will open in a new browser window. If you close the example window, this window should lie underneath.

#### Example 1:

Virtual Reality Markup Language (VRML). The following is an interactive 3-D world in which you can tumble around a dog trotting by clicking and dragging with your mouse when the "turn" button is highlighted (this is the default). The "plan" button will zoom in and zoom out. The "pan" button will move the scene up and down and right and left. You can jump between fixed viewpoints by clicking on the right and left arrows surrounding the word "view." The fixed viewpoints are side, frontal, posterior, and overhead. If you need to restore the scene to its original perspective, click on the "restore" button. Please leave the scene set to "study" and ignore the "goto" and "align" buttons. The scene will open in a new browser window. You will need the Cortona plug-in for Internet Explorer. It should be installed on the student computers at OSU's Veterinary Teaching Hospital. If you need to install it, it is located at [Parallelgraphics.com](http://Parallelgraphics.com). You can install it quickly and automatically on a personal computer at home by clicking on the preceding link. When you are done viewing the scene, close its browser window to return to this page.

Click to view the VRML scene of a dog trotting.

Example 2.

Predefined static viewpoint of motion capture animation of normal trotting (as seen in the Canine Lameness Learning Module).

[Click here to view example two.](#)

Example 3.

Predefined viewpoint of video of normal trotting (as seen in the Canine Lameness Learning Module).

[Click here to view example three.](#)

Example 4.

Sequential photographs of a dog taken by Edward Muybridge.

[Click here to view just the static photographs.](#)

Example 5.

Drawings of footfall pattern for a dog in canter.

Ranking of Preference:

Please rank from 1-5 with 1 being the most preferred and 5 being the least preferred.

1 The most preferred:

The options were: VRML, Motion Capture Animation, Video, Sequential Photographs,

Footfall Patterns

2 The second most preferred:

The options were: VRML, Motion Capture Animation, Video, Sequential Photographs,  
Footfall Patterns

3 The third most preferred:

The options were: VRML, Motion Capture Animation, Video, Sequential Photographs,  
Footfall Patterns

4 The fourth most preferred:

The options were: VRML, Motion Capture Animation, Video, Sequential Photographs,  
Footfall Patterns

5 The fifth most preferred:

The options were: VRML, Motion Capture Animation, Video, Sequential Photographs,  
Footfall Patterns

Comments: Please use the box below to elaborate on any of the above examples or  
explain if a combination of examples would help you the most.

Two matching questions were added to the end of the survey to see if the students could  
match a video of a dog to its motion capture animation, and vice versa.