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The Impact of Impediments on Quadruped Animal Locomotion

By

Hayden Mitchell Rogers

An Undergraduate Thesis Submitted in Partial Fulfillment

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Hayden M. Rogers

Date



April 12th, 2021

Professor Gregory Marlow, Thesis Mentor

Date



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Professor Marty Fitzgerald, Reader

Date



4/12/21

Professor Sarit Somasa, Reader

Date

Abstract

The topic that I have been studying for this thesis concerns the locomotion of quadruped animals. More specifically, my goal was to study how quadrupeds, such as canines or felines, move and then compare that movement to individuals of the same species, except adding in a factor such as a limp or the removal of an entire limb. I wanted to see how that affected their balance and their gait among other things. Luckily, there are plenty of resources out there for me to study the differences. Between videos online, living with dogs and cats at home, and semi-regularly volunteering at an animal rescue sanctuary, I have been able to amass a sizeable amount of data to determine both how these animals move regularly, and how injuries or the complete loss of a limb affects their movement. I have studied four different types of quadruped walk-cycles and then further studied them to see how various limb injuries affect how they get from point a to point b. Afterwards, I applied what I learned by animating a cycles that capture how the quadruped normally moves and then also animating a cycle where the quadruped has limited ability with one of its limbs.

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Acknowledgements

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Introduction

Since the beginning of my experience with animation, I have felt drawn to creature animation. I would always grow particularly interested in watching films or video games that featured creatures. Something that I have noticed across the many demo reels that I've looked at is that when they do include creature animations, it is often a creature that appears to be in perfect health. After I began volunteer work and met two amazing goats with impediments affecting how they walk, I started thinking about how little representation I have seen for impediments, especially of creatures, in animation. That is how I came to my thesis; to see how an animal adapts how they walk or run when they do have an impediment, whether it is a limp or even the complete loss of a limb.

Standard Cycles

One of the most important things I had to do for this project was determine what creatures to focus on for the study. One way that I narrowed everything down was by deciding to limit myself to quadrupeds, which took out creatures such as birds and insects. From there, I spent a decent amount of time studying various animals walking or running, just to get a feel for what would be fun to create in Maya. One thing that I did end up taking into consideration was that I had no prior experience involving projects, school or personal, with creatures prior, so I ultimately decided that the early part of this study would involve me learning basic creature walk cycles before moving into more complex movements.

Dogs and cats are the most common animals that I see in my day-to-day life, so it made perfect sense for me to begin studying how they moved before moving on to something more complex. The first thing that I tried to perfect was the foot placement. There is video by Jamie Capsolas on YouTube that I was able to look at that illustrated the gait of canines. At the dog's most extended position, where one of the front limbs has just planted onto the ground, the limb that has just planted will be the furthest forward, followed by the other front limb. The back limbs are set up in a similar manner, with the back limb on the same side as the planted limb being in front of the other limb, which will be extended backwards, waiting to spring off of the ground.

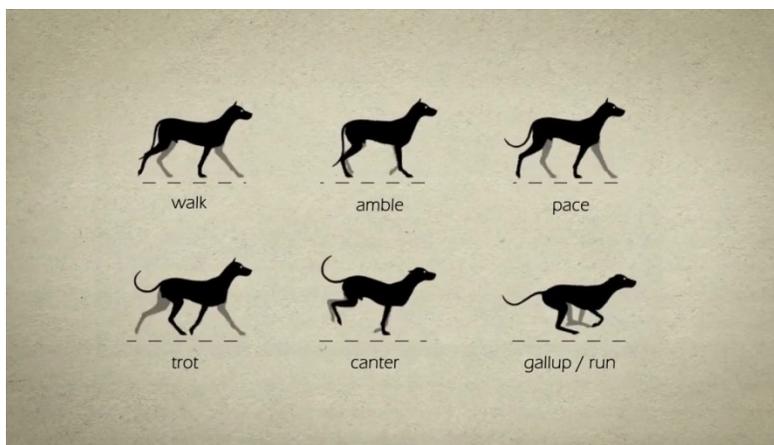


Fig. 1 (Picture showing the different gaits that animals, such as canines, possess)

Outside of the limbs, the other important piece in making the walk look natural is figuring out how the torso reacts alongside the leg movement. With each model that I used, across the board with canines, felines, and deer, I learned to treat the chest mass and the waist mass as two separate entities being controlled by the pair of legs branching off of them. If one leg rose off of the ground, the torso tended to rotate towards the remaining planted leg in order to best balance itself. Doing the alternative would give too much weight and not enough support

and result in the animal losing its balance. Outside of rotating these masses, it was also important to work with translating the torso, particularly along the y-axis. I utilized picture diagrams from Richard Williams' *The Animator's Survival Kit* immensely to help with this (along with the feet placement in parts). Within the diagrams, there were labeled points that specified roughly when the chest or pelvis would be at its highest or lowest point. The same diagrams covered the squash and stretch principles within the cycle and it stated that the core animation of each animal is similar. Once you are knowledgeable about one cycle, you can base subsequent cycles on it with changes depending on the animal.

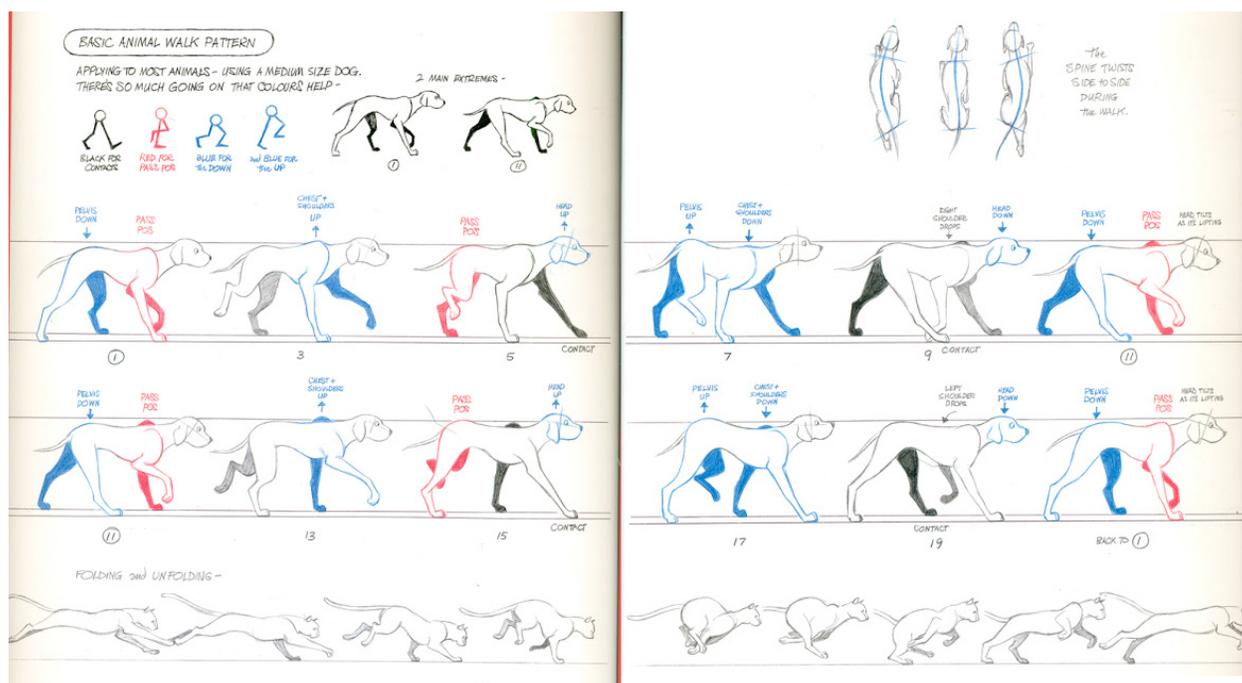


Fig. 2 (This diagram from *The Animator's Survival Kit* illustrates mechanics that go into animating quadrupeds)

I was able to confirm the books finding by finding reference that showed animals actually going through the poses that Richard Williams shows. This video in particular is good, as around the twenty-eight second mark, the video shows a slow motion video of the wolf walking, where it matches the pictures drawn very closely.

<https://www.youtube.com/watch?v=0XnvkuLuzV8>

Something that I found to be a challenge when animating all of the creatures compared to the usual human character rigs that I am used to is how the anatomy is different. If we take a look at the diagram below, dogs and humans possess many of the same bones, but the proportions are a lot different. Whereas our heel bones are laid out horizontally, in dogs (as well as cats and deer) that heel bone is placed more vertically, which pushes their other leg bones further up into their body. The way these animals stand normally is roughly the same as if we stood on the tips of our toes.

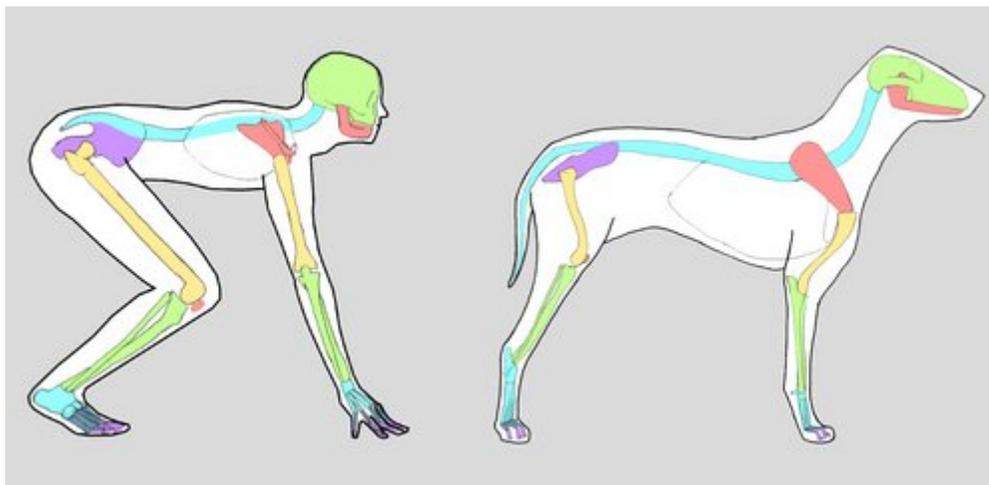


Fig. 3 (A comparison of the anatomy of a human and a canine)

Something that I noticed when animating the deer, especially, was the arcs of the legs. I noticed that the front limbs seemed to have a higher peak, but traveled a bit less distance over the course of the cycle. The back limbs had the opposite journey; they did not reach quite as high, but they covered more horizontal distance than the front limbs. I believe that is largely due to the anatomy of the animal. Its ankle bones extend even higher up than canines and felines.

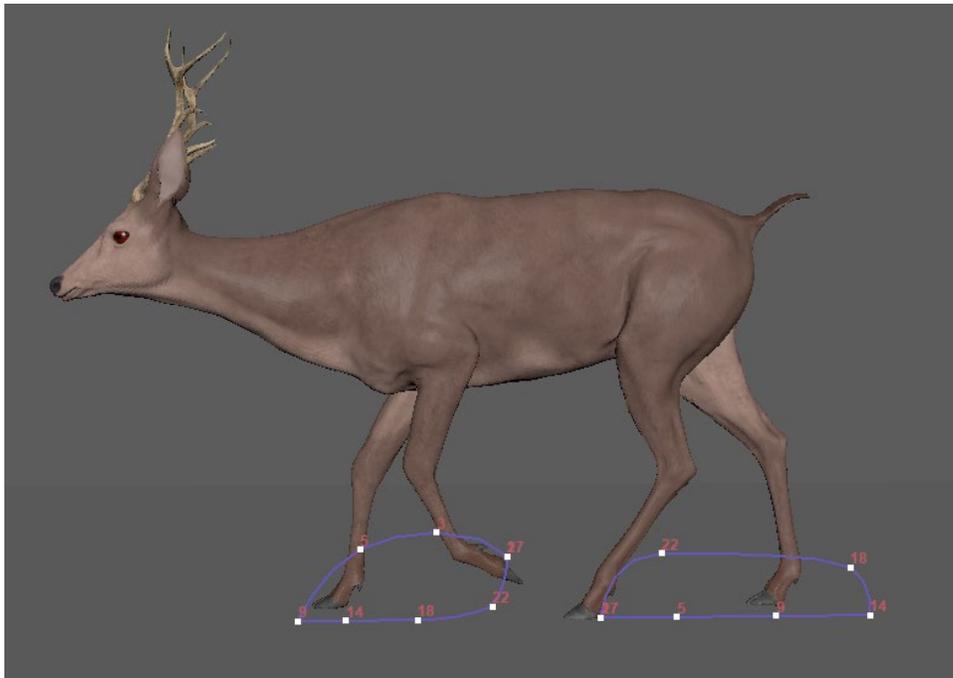


Fig. 4 (Using editable motion trails, I tracked the arc of the quadruped's feet)

After I completed each creature's walk cycle, I would then focus on how they move while running. One key difference between the walking and running cycles is that in the latter, there is a moment where all four legs are off of the ground. The back legs will actually be in front of the front legs for a brief moment, as the limbs push against the ground to carry themselves more quickly. In more extreme run cycles, the limbs may even be off the ground when the limbs are at their most extended point.

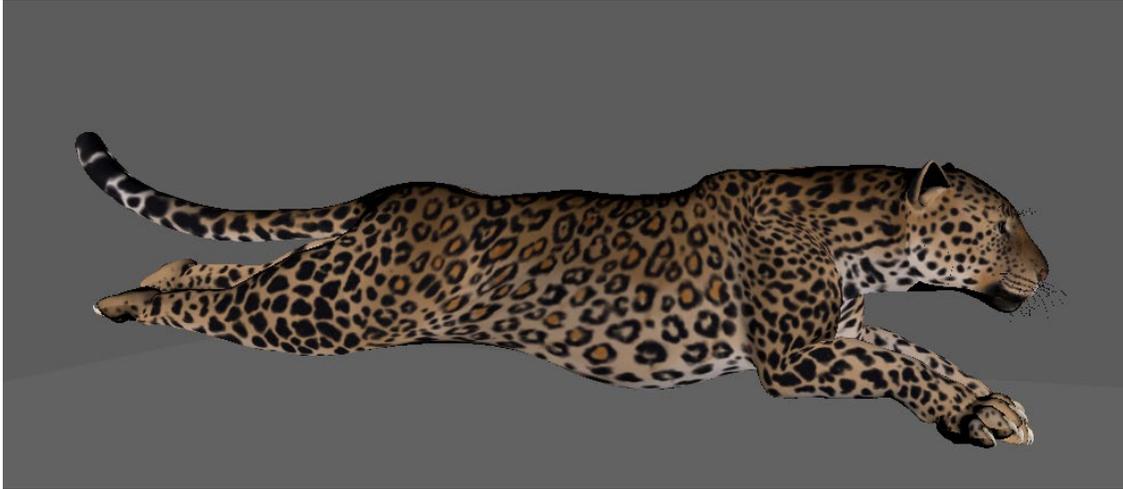


Fig. 5 (In this pose, none of the leopard's feet are planted on the ground)

In most other cases, however, the most extended the creature will get is as the limbs first begin to make contact with the ground. One key thing to note with each set of limbs is that they are overall much more in sync than a walk cycle, but they still plant onto the ground at slightly different points.

One other difference that I experienced when animating the walk cycles versus the run cycles was how many frames I had to make the action apparent. Looking at how many frames I had for each cycle, the walk cycles varied from twenty to thirty frames each, while the run cycles ran between thirteen and fifteen frames. With only half the frames to get the speed of the run feeling right, I had to make sure to really sharpen up every pose to make sure that the running pieces turned out as strong as the walk cycles.

Impediment Cycles

The final step in each set of cycles that I did was a cycle in which the creature had an impediment that shifted the way that they moved. Between my creatures, I focused on a limp, the loss of a front limb, and the loss of a back limb. In all three cases, the limb was unable to plant itself on the ground (whether voluntarily or not) so the other limbs and the torso had to pick up the slack.



Fig. 6 (For both the wolf and deer impediment cycles, I had to modify the models before animating)

For instance, if one of the front limbs is not contributing to the forward motion, the remaining limb's general position will move inward to create better balance. The torso will also move and rotate to the side of the remaining limb as it offers more structure to hold the body.

Another thing that I picked up on both from watching reference from videos and from my own experience with one of the goats at the Animal Rescue I volunteer at is the lone limb, regardless of whether it is in the front or back set of limbs, makes more of a jumping motion rather than a step. The reason for the leap in place of the step is due to there not being an extra limb to support the weight of the torso so the step has to be made much quicker. The same thing happens with a limp. The animal will go through with a hop instead of a step so that they do not have to put unneeded pressure on their injured limb.

The process for creating the impeded cycles had a few added challenges compared to the standard cycles. I had to work harder to make the weight feel correct. Not only did I need to make the base weight feel good, but I had to make the weight feel right while considering the fact that each quadruped was also compensating for having one limb not touch the ground at all during the animation. One thing that I did to achieve this was move the lone limb inward so that the base stance did not have a big area of empty space that would drag the body down otherwise.

Another thing that was different between the standard cycles and the impeded cycles was that I had to add an extra level of momentum to get the movement looking right. Between all the reference that I found of three-legged animals, I noticed that the head (and consequently the torso as well) seemed to angle itself much lower before releasing a burst of energy when they took a step with the single leg. There was a fine line that I had to hit to make sure that it looked realistic and not too snappy.

The biggest benefit that I got from the whole process of animating these cycles was the in depth attention that I had to give to things like the anatomy, the arcs of different body parts, and the weight. I could have simply watched the videos and said, “Yeah, I can see what’s going on here”, but trying to create my own rendition of that same motion really made me think about just what was going on with each animal.

Conclusion

I am very happy that I was able to center my study on animals; even moreso that I could focus on the impediments. It felt unique to me and it was something that I felt very passionately about. Through doing this, I feel as though I really grew as an animator. I have a stronger sense of what I would like to be doing when I finish my education and move on out into the world. This study is something that I would love to revisit in the future. I studied three different animals, but there are so many other animals that I would love to really study and learn more about how they move around. I also would like to apply my studies to an impediment and run combination, since I focused on applying those to walk cycles for this project. I am pretty satisfied with what I was able to accomplish and I feel like out of everything that I have worked on over the course of my time as a student, these are among the stronger pieces that I have created.

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