

Kinematic Variation
Subsurface Toe Motion of Birds

CS 137 Assignment #4

1. Dates

Introduction	Thurs 10/19
Part A Sketches	Tues 10/24 and Thurs 10/26
Part B VR Critiques	Tues 10/31 and Thurs 11/2

2. Goals

1. Use visualization tools to display several variables of data while maintaining legibility, focusing on the anatomical side of the interaction between foot and ground while a guineafowl walks through substrates.

3. Readings

Check out Morgan's slides and other media on the course website.

4. Scientific Background

Morgan's main interest is on how animals use their feet to interact with their environment and move around. There can be a lot of variation in how feet are used when walking. Related to Steve's work on how dinosaur footprints are created, Morgan focuses on exploring patterns within the diversity of bird foot kinematics (motion) and identifying landmarks within the motion which are detectable and measurable in fossil tracks.

Currently, Morgan is working with a lot of data on the feet of guineafowl, a chicken-like bird found in South Africa, as it walks through different substrates (eg, solid, dry granular, firm and solid muds). From reconstructed animations of the walking animal, Morgan uses known 3d coordinates through time to create motion trails from specific locations on the anatomy.

Currently the focus is primarily on tracing the tip of digit III (the middle toe) of both feet of the guineafowl through a series of steps, both above and below the ground. Interestingly, when the foot sinks while walking on deformable substrates, the resulting motion trail almost always takes the form of a series of loops through space. The shape of these motion trails change depending on what substrate the animal is walking on (foot sinks deeper on sloppy muds than dry granular sediment), but also change depending on several elements relating to locomotion (eg. previous step length, when the other foot is in contact with the ground, etc).

Consider the following human scenario: Imagine you have motion trails (or lights attached to your feet and take a long exposure photograph) tracing the position of your feet as you walk for 10 seconds. The motion trails are a record of 3D position through time. Now, imagine you want to display several events which occurred during those 10 seconds. Events such as: when each foot is in contact with the ground or in the air, or when your swing foot passes just over your

stance foot. These are kinematic events. Now imagine the distances between each step, you could measure how far apart they are along the direction of travel, or how wide they are measured perpendicular to the direction of travel, or even the highest point of the swing foot over the stance foot. These are explicit measurable distances. Finally, imagine the angle of your ankle as you walk -- it changes throughout the 10 seconds of walking.

There are several types of data here: events based in time, locations along the pathline dictating distances based on cyclic patterns of walking, and dynamic measurements dependent on time and space.

How might you display a dynamic measurement along the pathline?

What symbols and colors might you use to represent events?

How might you display the variation in any of these events or measurements for several steps or several people?

Like humans, birds are bipedal and walk with a similar gait. Instead of humans in the scenario above, Morgan has the same types of data recorded from living guineafowl.

Morgan's Theories

1. Feet move differently on different substrates
2. Foot movement is variable even on the same substrate type
3. There are relationships among variables of subsurface foot motion

Morgan has data that support these theories and is confident in using them as a foundation for several, unanswered, bigger questions.

Morgan's Big Questions

1. Are there consistent relationships between the kinematic events and measurable loop geometry?
2. Does the geometry of the toe path relate to the motion in the rest of the animal or the substrate type the animal walked through?
3. Can geometry be measured in fossil tracks?

If all of the above are true, can fossil tracks be used to reveal insight into both substrate and kinematic conditions during the creation of the preserved track?

Several important kinematic events and landmarks have been identified and measured along these toe paths, however; visualizing the large dataset of foot motion, accompanying variables, relationships of both feet, and overall patterns has remained a challenge.

5. Assignment

Morgan struggles with displaying and interpreting the layers of variables necessary to get a more holistic understanding of the relationship they have to the final form of these toe path loops. Your assignment is to design visualizations to explore patterns in her data. You don't need to use the real data, feel free to use fantasy data. Using the scientific background, and the materials provided by Morgan, design a visualization strategy that can achieve some of the following goals:

- Indicate the path of the feet or toes through space and time
- Display variables along pathlines
- Summarize variation in the large dataset of toe paths
- Summarize variation in foot motion (see “variables to consider” below)
 - Perhaps consider featuring variation of just a single toe, joint between toe and metatarsus, the whole foot, the space the foot occupies through time, or some other anatomical element.
- Make use of the three dimensionality of the YURT (what can't we do in 2D?)
- Make effective use of visual tools (eg. color, form, size, context, sequence)

Variables to consider:

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| Toe spread | (dynamic measurement) |
| Ankle or MTP (metatarsophalangeal) joint angle | (dynamic measurement) |
| Substrate type | (solid, dry granular, firm mud, sloppy mud) |
| Kinematic events | (time; eg. first and last contact of foot to surface of ground) |
| Specific measurements of loop geometry | (eg, loop width or depth) |

Context to consider for your design:

- Where is the surface of the substrate?
- What are the units of distance and coordinate system?
- Is a legend of colors and symbols needed?
- How does the user interact with the data?
- Are display layers useful?

5.1 Part A:

Towards the final design goal, you should begin by making sketches showing various approaches to displaying data and volumetric configuration in 4D (three spatial dimensions plus time) keeping in mind what your visualization would look like once executed in the Yurt. The issue of time sequence can be addressed using toggled frames, as a 3D object or image showing all sequential steps at once, or as a combination of both. In both cases, consider providing a graphic context to clarify issues of spatial position and time steps: a grid, bounding

box or scale of some kind. Add a legend or key to explain how the data is displayed, if necessary.

Your model should involve at least four frames which you or an assistant will cycle through in “Wizard of Oz” technique. If your model traces a sequence through time, then the frames can be keyed to a time sequence. If your model shows time sequence in a single image or object, then your frames might show a changing sample or highlight within the data.

For next Tuesday, you should feel free to bring in as many sketches as you like, perhaps comparing different ideas, structures, connections and gradient choices as they occurred to you during your design process.

Choose a specific aspect of Morgan’s science, as listed above, for the focus of your project. Study the animations and other materials from Morgan, and then determine a hypothesis for your visualization that shows, for example, how do the toes spread throughout a step? As mentioned above, you may concentrate on displaying the relationship of the feet, a single variable for several trials, or several variables for a single trial. You can include as much contextual information as you think is important: anatomical specifics of the larger foot, leg or other anatomical structure; specifics of surrounding substrate or forces at play within it; aspects of the overall visual environment such as substrate surface and layers or artificial narrative devices such as a running track, treadmill, landscape elements etc.

Your ultimate concern, however, should be the legibility of your depiction of Morgan’s data. Visual extras should enhance, or at least not interfere, with user perception of this data. Consider the role of abstract graphic structure and gradients in providing clarity and precision. You should be ready to explain why your various choices are important and how they relate to the central data variables.

The crit will be in the classroom.

5.2. Part B: Put your design in CavePainting. Consider how a legend for colors and symbols used, user interactivity, and display layers might be efficiently integrated with the experience of virtual space. What is the most effective sequence for you to present your project to the class, to visually communicate the relationship of the feet, and the variables from the data? Remember, this can be a design plan/interface/tool which has the potential to be implemented by a scientist (in this case Morgan) and you should approach the scripting of your performance through the senses and priorities of an imagined user.