Overview: The whiskers are a very important sensory organ. Here I’m showing a video of how a rat uses its whiskers to acquire tactile information about the world. In this slow-motion you can see how the animal active moves its whisker back and forth, and this behavior is called “whisking”. (and the back and forth is called the protraction and retraction of the process) This proves to be one very important behavior that uses a sensorimotor feedback loop.

So, a one-sentence summary of what I want to do, is that I want to build a model that simulates this process mechanically, but no the entire rat, so more specifically we will cover an entire array of whiskers and follicles, and the muscle that actuates them.

And another important background information is that the follicles (which are the bases of the whiskers) are well organized on animals cheek. For example a rat, it has 5 different rows (A, B, C, D, E) and several columns.

In order to make the follicle move, so that the whisker can move, there are basically three major parts that are very important in this process.

**Slide 6**: The first is the intrinsic muscle. (These are not slides designed for today, so you don’t need to read the text) So, an intrinsic muscle will connect two adjacent follicles in the same whisker row. It originates from the apex of the caudal follicle, and wraps around the lower part of the rostral follicle. So, the contraction of this muscle will cause the rostral follicle to rotate, such that the whisker will move to the opposite direction. So in this case the follicle moves caudally, and the whisker moves rostrally. So you see, the contraction of the intrinsic muscle plays a very important role in whisker protraction.

**Slide 7**: A second very important part of this process is extrinsic muscles. Of all of the facial muscles, there are 5 groups of extrinsic muscles that affect the behavior of whiskers.

**Slide 8**: This is a series of simple illustrations to show how these muscles originate from different parts of the face, and insert into the whisker pad from different direction. In this figure below you can also see that these muscles insert into the pad at different levels – some superficial, some towards more deeper level. Also, importantly, besides the intrinsic muscles, all of the other muscles don’t make direct contact with the follicles. So they come and go in the space between the follicles. This feature will become important in the modeling.

**Slide 9-15**: This is an illustration made by me to show their relative sizes and position altogether.

**Slide 18**: Besides muscles, there is a third structure that’s important in whisker movement, called “the collagenous skeleton”.

**Slide 19**: It’s sort of like the connective tissue that fills the room between muscles and follicles, but they mainly exist at the superficial level (which is right below the skin epidermis), and a deeper level (sometimes deeper than the follicles). The function of these structural protein layers is that, after the follicle (especially the deeper end of the follicle) is displaced, this sheet will deform and store the elastic energy, so that after this process, the animal won’t need another set of muscles to pull the follicles back to where they were. The tissue will act like a sponge, and will push the follicles back. So you see, this collagenous layer is also an important component of this dynamic process.

**Slide 22**: now, before constructing this model, I want to show two models that existed in the field. The first one simple (1) follicle connected by intrinsic muscle (2) top and bottom anchored, independently.

**Slide 23**: The second one (1) follicles connected to each other (2) extra component to simulate extrinsic muscles.

Compared to these models, in our model, we wish to (1) turn everything into 3D (2) the same time, because the complexity of all those components, we want to make as much simplification as we can (3) (at least) implement actual dimensions of follicle, also make the positions and properties of those muscles as accurate as possible (you see in their model, it’s been simplified a lot, and people actually cannot make any biomechanical conclusions)

**Slide 24**: So for us, we want our model to be build based on this, this is data for follicle position and sizes cleaned from another anatomy experiment

**Slide 25**: Next I’m going to talk about some detailed model design. I will demonstrate using this illustration of four follicles in 3D – two rows and two columns. So, they’re inter-connected by dampers and springs to represent the passive force from the collagenous network. Each follicle is also connected to the skin epidermis represented by rigid ground, to sort of anchor the whole system at a fixed place (in the simulation environment). Each adjacent follicle in the same row is also connect by intrinsic muscles. I will talk about the details of muscle in a minute.

**Slide 26**: Then for the extrinsic muscles, they are much more complicated. Like I said before, they are from directions at different levels, and they also do not make direct contact with the follicle. So I’m thinking to model the extrinsic muscles as a chain of muscle components, so that we can approximate this soft tissue using rigid body dynamics. Each muscle component here will contract like a regular muscle. The exact positions of these muscles, I approximated them from anatomy descriptions.

**Slide 27**: Then we add springs and dampers like the ones we used to represent the tissue, so that the force generated in the muscle can be passed to each nearby follicle at different insertion location. In this simulation, we will have all of the extrinsic muscles all be modeled in this form. And then I wanna talk about the details of how we want to implement the muscle contraction (whether its intrinsic muscle, or a muscle component in the extrinsic muscle)

**Slide 37**: So this is the idea for muscle contraction, which hasn’t been implemented yet, comes from a modeling paper which describes the relationship between muscle force and muscle length, and also its speed of lengthening. (Do you want me to describe the plot?)

**Slide 38:** So my understanding of this equation is, (describe step-by-step)

So I guess my first question is: is this a correct interpretation of the muscle contraction process?

Then if I converted to pseudo code, I realize that the activation level is the only parameter that being modulated at each simulation step. Then my second question is, how does the muscle activation level change (maybe a function of time)? What is the reasonable assumption that’s helpful in the modeling process?

And before this question, I think I also want to know that (Slide 37) whether or this Hill-type model is universal or not? (can it be applied to rodent facial muscle)

That doesn’t mean we do not want to validate this model at all.

Q: what do people usually do to find the parameters of all of the muscle? Or make association with what’s already know. (For example I could maybe set the stiffness of these different muscle based on their thickness)

Q: how do people usually validate the dynamic properties of a muscle model like this?