Art-Directed Costumes at Pixar: Design, Tailoring, and Simulation in Production

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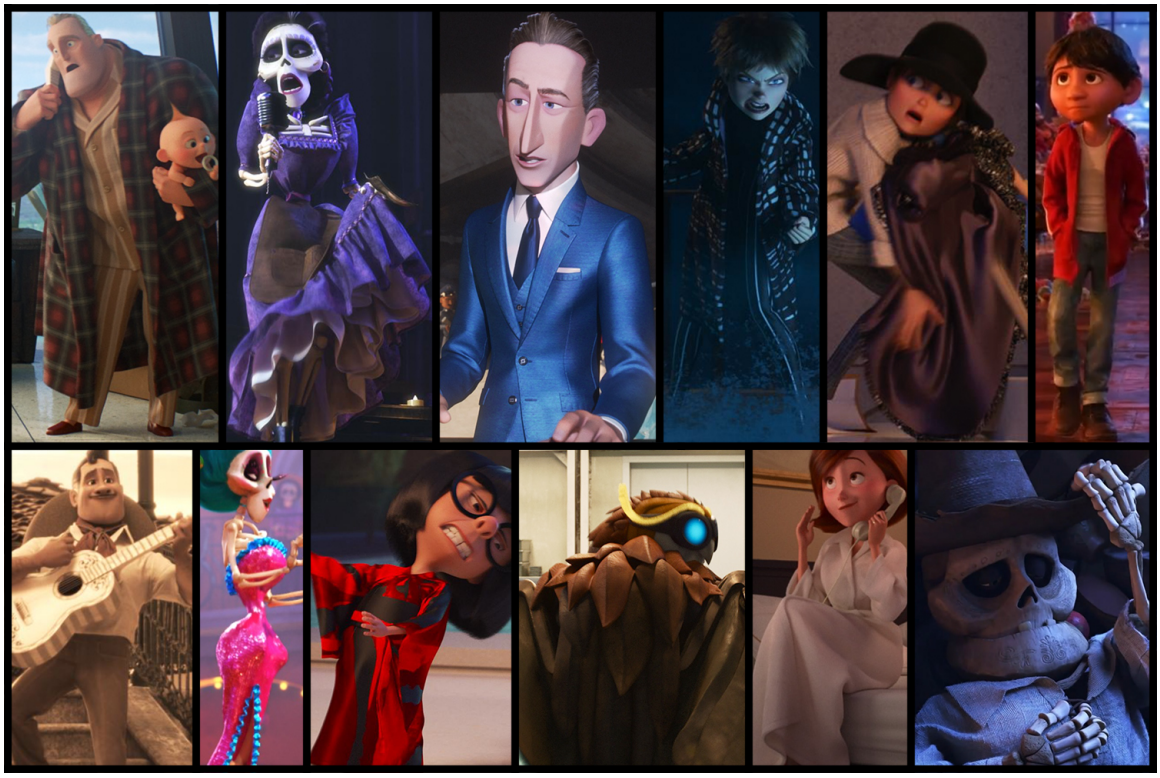

Figure 1: Costumes at Pixar

ABSTRACT

Costumes are an important part of character design, acting, storytelling, and visual appeal in animation. However, it is challenging to achieve art-directed natural-looking motion and detail in CG animated clothing, due to technology, workflow, and budget constraints. This course will cover Pixar's latest approach to CG costumes, from design to tailoring to simulation, and how we try to address these challenges. Our goal is to continue working towards a balance between the detail and physicality of real costumes, and the stylized artistry and movement of 2D animated clothing.

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Using examples from "Incredibles 2", "Coco", and other Pixar films, we will show how our artists approach the initial costume design direction, strategically plan designs to fit within time and technology constraints, and translate drawings into 3D clothing on stylized characters. Next, we will show how we create garment models using 3D and flat-panel tailoring methods, applications for common simulation parameters and settings, and robust out-of-box simulation techniques using cloth rigging and dynamic alterations. Finally, we will cover the tools used to simulate garments in shots, create appealing shapes and movement, and help Animation let the characters act with their clothing. Although Pixar uses proprietary tools, the principles can be applied to other pipelines. Along the way, we will talk about how the tailoring and simulation teams collaborate and fit in with other departments, such as Rigging, Shading, Animation, Art, and Crowds, as well as the current state of our technology and tool set. We will cover material for all levels of experience, with backgrounds ranging from artistic to technical.

CCS CONCEPTS

• **Computing methodologies** → **Animation**; **Physical Simulation**;

KEYWORDS

cloth, costumes, costume design, tailoring, cloth simulation

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Introduction

- Costumes are a very important part of all films. They tell you so much about the characters' personalities, and how they change over time.
- They provide a visual shorthand for the story's setting.
- They can be an extension of the character's acting performance.
- Clothing movement can heighten emotion and drama in a scene.
- It can add to the cinematic performance, using visual framing and silhouette in shots.
- If these unspoken qualities are done well, you can feel more immersed in the world and leave the theater with a greater sense of inspiration.
- It's a feeling!

Introduction

- In CG animation production, there are three important criteria: Correctness, Efficiency, and Beauty

- For CG costumes, this might mean:
  - **Correctness** - The garments are made with correct cuts and panels, and the cloth simulator does a good job at approximating reality
  - **Efficiency** - We can model garments quickly, the simulator is fast and stable, and sims run out-of-box without much cleanup
  - **Beauty** - The costumes are artistically appealing and interesting, and add to the story and emotions in an unspoken way

- Sometimes we emphasize Efficiency, because the movie should be made on a reasonable time and budget, or Correctness, because there are clear goals for targets and improvements

- Beauty is less defined and hard to quantify, but equally important

- This course will attempt to show how Pixar tackles all three categories

Course Outline

- Design
- Modeling Garments
- Simulation Setup
- Improving Out-of-Box Performance
- Cross-Departmental Collaboration
- Shot Simulation

In this course, we'll talk about the theory and practice of Pixar's approach to creating and animating CG costumes. CG costumes require a mix of technical and artistic knowledge, from costume design, to modeling, to simulation setup, to shot simulation/technical animation, and in some cases software engineering and scripting (though we won't cover that in this course). It is also important to understand how to work with other departments, such as Character Modeling and Rigging, Shading, Crowds, Art, and Animation. These are the teams that contribute to the final look and performance of the costumes as well.

Note that although most of our tools are proprietary, the concepts might be interesting and applicable to outside studios.

Design

Design Overview

- Costume and character design in CG animation has many challenges:
  - Finding the best look for the character that will support the story and character arc, after exploring many possibilities
  - Collecting reference to support design choices and look at when tailoring and simulating
  - Solving the creative problems that often arise from budget and technology constraints
  - Translating drawings to 3D form and hitting appealing shapes
- Finding solutions to these challenges requires a joint effort from concept artists and technical artists

Ideas About Appeal

- It is good to have contrasting visual elements in different amounts
  - Large shapes vs. small shapes
  - Straights vs. curves
  - Patterns/texture vs. flat colors (or different patterns)
  - Positive vs. negative space
- Think about size and placement of elements, be selective and show restraint
- Think about shape, silhouette, and proportion
- Don't design for design's sake - try to tell a story. Simplicity is often more difficult because simplification must inform form and serve a purpose
- Avoid perfect CG symmetry and cleanliness
- Visual flow: carry the eye around the image, draw eye where you want

Note: "Appeal" is a difficult concept to define, and there are many resources and opinions out there on what it means. We will try to summarize the thoughts of a few Pixar artists and point out specific examples of why something might be appealing throughout the course.

The goal is for these concepts to make it into the final pixels of the movie. So everyone from concept to technical artists should keep practicing, making mistakes, and thinking about work with a critical eye. This is the only way to further develop intuition for appeal, and we are always improving. Look at reference and figure out what you like and don't like about it. Good taste is linked to interest and knowledge of many different things.

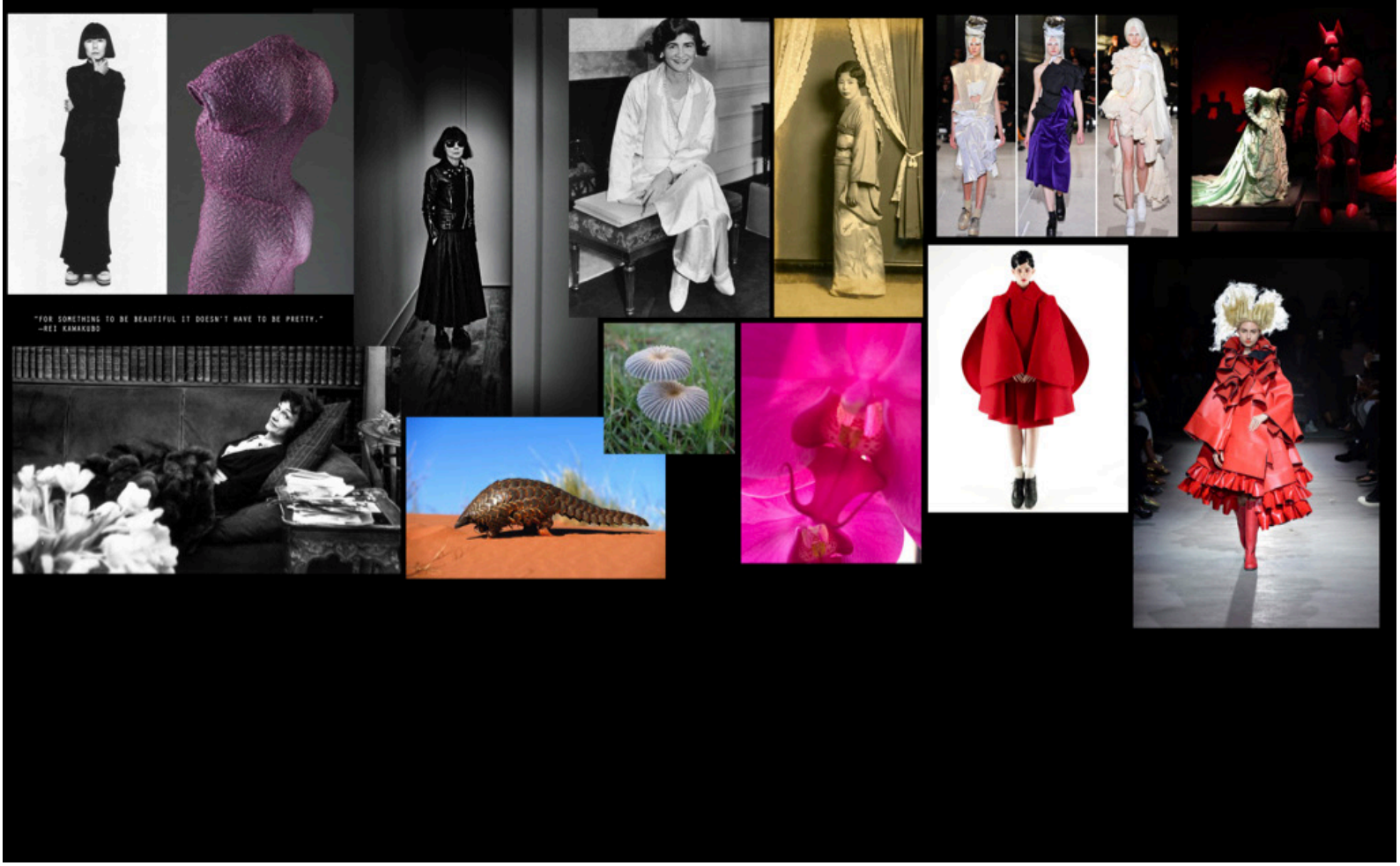
Learn to pay attention to whatever you're currently working on, whether it is Victorian Era Mexican dresses, bespoke suits, anime-inspired clothing animation, etc.

Taking Inspiration

The first thing the costume designer does is gather reference of people/actors and clothes that embody the spirit and time period of each individual character.

These are some of the many references from *Incredibles 2*. Among others, Bob is like Paul Newman - a handsome, robust, family man with integrity. Helen is becoming a Super again, so Mary Tyler Moore, Audrey Hepburn and Marilyn Monroe were strong, career-minded and fabulous examples to be inspired by. We also take note of small, time-period details: like plaid, pearlized buttons, leather watch straps, sunglasses, and clean, simple lines. These guide us in making decisions about overall looks.

Taking Inspiration

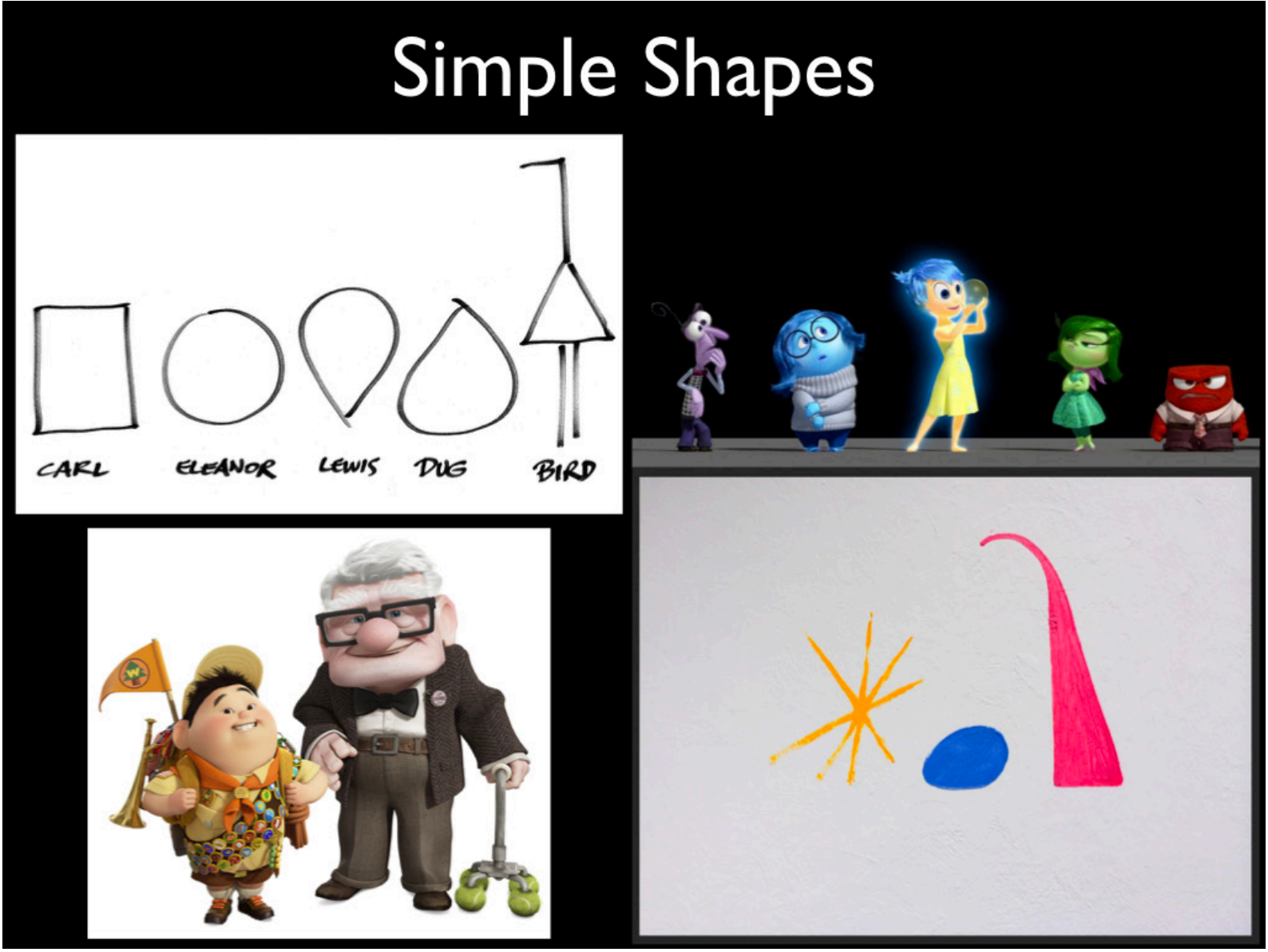


For Edna Mode, Edith Head was one of the designers that we looked at in the first film. But since Edna is German and Japanese, we looked at a few Japanese fashion designers and what they tended to wear.

Rei Kawakubo, Eiko Ishioka and Chitose Abe always look comfortable in what they wear, but in contrast, the costumes they design are outrageous and uncomfortable-looking. Rei Kawakubo stated that “For something to be beautiful, it doesn’t have to be pretty”. We thought this was in line with Edna, and started to think about her costume as a piece of sculpture rather than normal clothing. We also looked at nature to be inspired - animals, mushrooms, and flowers.

Taking Inspiration

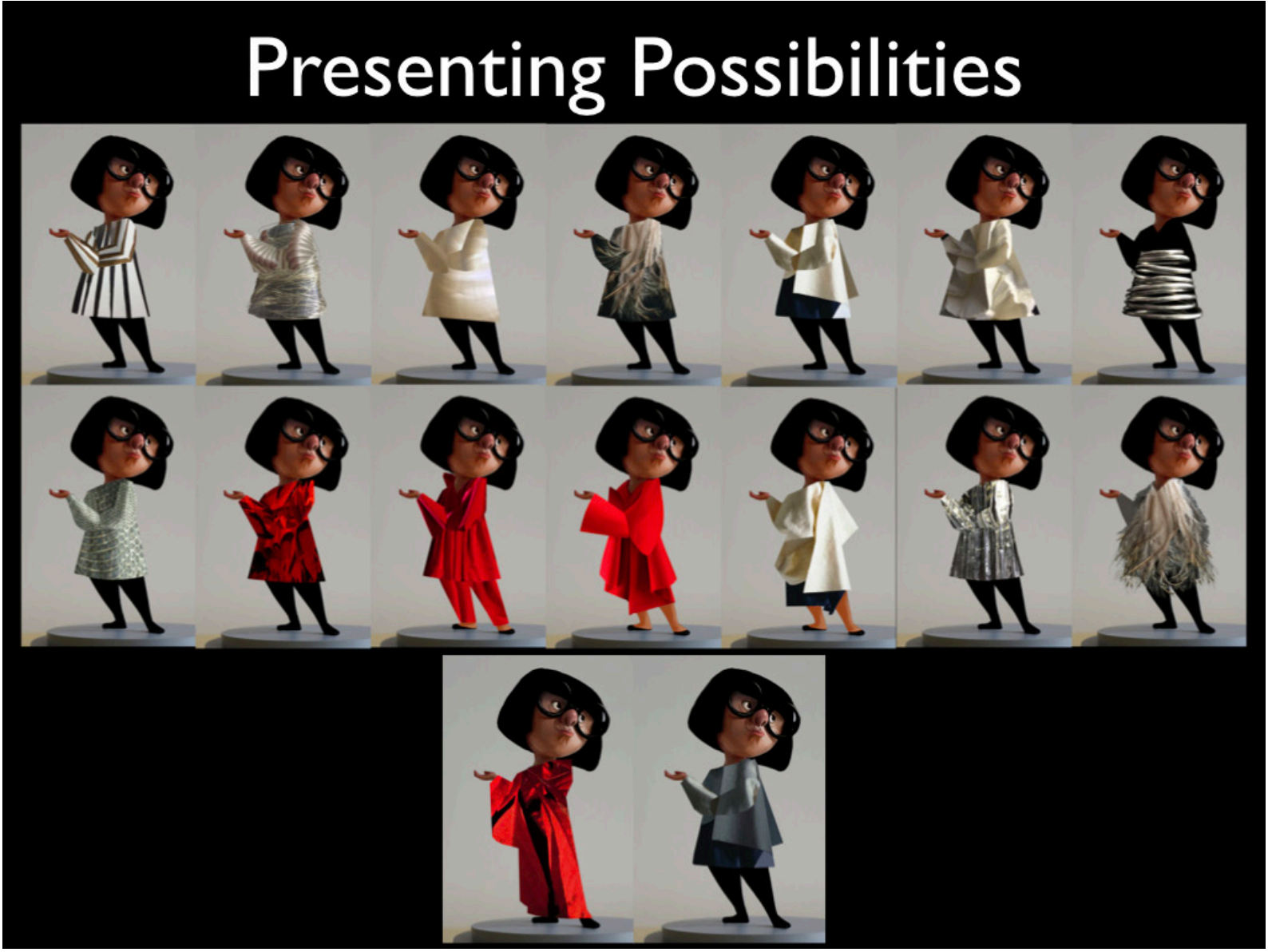
On *Coco*, we tried to do as much research on Mexican culture as possible, to portray it respectfully and artistically. We looked at many classic Mexican paintings by Diego Rivera, José Guadalupe Posada (La Catrina), and others for clothing inspiration. We looked at Jalisco skirts in motion as reference for the dancing scenes. We looked at Frida Kahlo's clothing for design inspiration and for her character. In the Land of the Dead, we wanted people from different time periods and backgrounds all mixed together - Victorian, Mexican Revolution, 1930s, Contemporary, and more. We had to choose a few key time periods that would encompass the culture (in a good way).



On *Inside Out* and *Up*, the characters were inspired by simple shapes. Carl is a square and Russell is a circle. Joy is a star and Sadness is a teardrop. We use costumes to help create those shapes, and also to bring out the characters' personalities. Joy's dress moves and swishes and flows in a joyful way, Sadness uses her soft sweater to hide, and Disgust's skirt is tight and stiff like her closed-off attitude.

Shape Informs Character

Coco was much more realistic than *Inside Out* and *Up*, but we could still make use of strong shapes to tell you about the characters. Imelda is stern, proud, and severe, but with a hidden softness. We wanted her dress to be true to culture and show that softness by including ruffles, but shape them in a striking, angled, severe way. The hard points and lines of the ruffles and square neckline show her hardened character. Also, having the ruffles be the same color as the dress makes it look less frivolous and fancy.



Graphic shape and silhouette is also very important in *Incredibles 2*. For Edna, using collage, we tried different materials and garment construction to create her iconic triangle shape. They all have different feelings, and director Brad Bird chose the bottom two in the end.

Character Arc Through Costume

Characters will often have a progression throughout the movie, and costumes are a great way to help show that visually.

Evelyn's costumes blur gender lines, some with masculine cuts, and some with a more soft and feminine approach. This hints at her divergence from typical mid-century gender roles, but also shows she can blend in and pretend to be someone else. Throughout the movie, her costumes become more harsh and striking, resembling the Screenslaver patterns and revealing her true character.

Bob's clothing design progression shows a slow decline in his confidence, getting messier and messier at his lowest points. He then makes a recovery and starts to dress more confidently. This is represented by the fit, wrinkliness, and color of his shirts.

Imaginative Design

Here is Edna's bold and dramatic couture fashion line, inspired by different superpowers, such as strength, flight, and x-ray vision. This is an example of how much fun we can have as designers! Costuming is an opportunity to actually BECOME the character. With all the unique construction challenges, designs like these keep technical artists excited too.

Note the appealing contrast of large vs. small shapes - large elements of cloth and skinny limbs, smooth cloth vs. textured cloth. There are contrasting colors but a limited palette, showing restraint. On the lower picture, there is a clear visual flow directing your eye to the model.

Costumes != Fashion

Not all characters are super fashionable in the traditional sense, but they can still have very artistic designs. Often artful sloppiness or unique and specific clothing make sense for the character. In these cases, principles of appeal and shape language are more important. It becomes more about telling a story with the costume and showing personality.

But it is still useful to understand common fashion and style “rules”, to know when to apply them and when to ignore them.

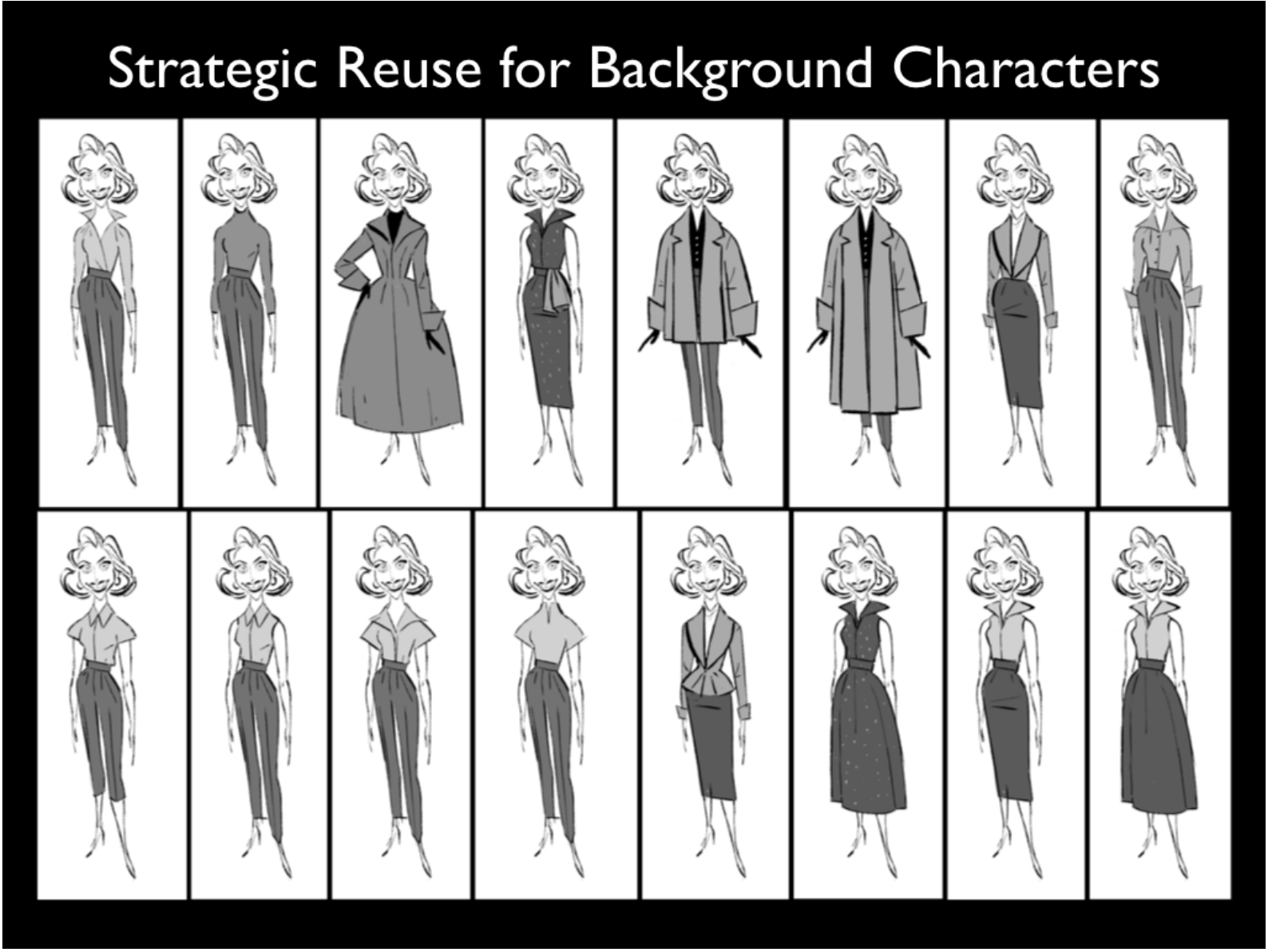
Strategic Reuse for Background Characters

For BGs, it is important to get the most variety you can with the fewest number of garments. By keeping the same waistline for all pants/skirts on a body type, we could easily mix and match tops and bottoms. Shading variants can be used to change looks from Victorian to 1930s formal-wear. On *Coco*, we needed to create many different kinds of costumes from different time periods.

Designing a crowd is a special challenge that requires a different way of thinking than for main characters. We want them to look more generic, and it is not bad to see repeating elements in the mass of people. If you squint your eyes, it creates a pattern. The statement of the crowd is colorful, and provides context for the main characters.

Strategic Reuse for Background Characters

Note how although the clothes are realistic and have a lot of folds, there is still an overall simplicity to these designs. Large shapes vs. small folds. Your eye is drawn to the strong shapes first, and the small folds almost read as a texture, filling in the shapes.

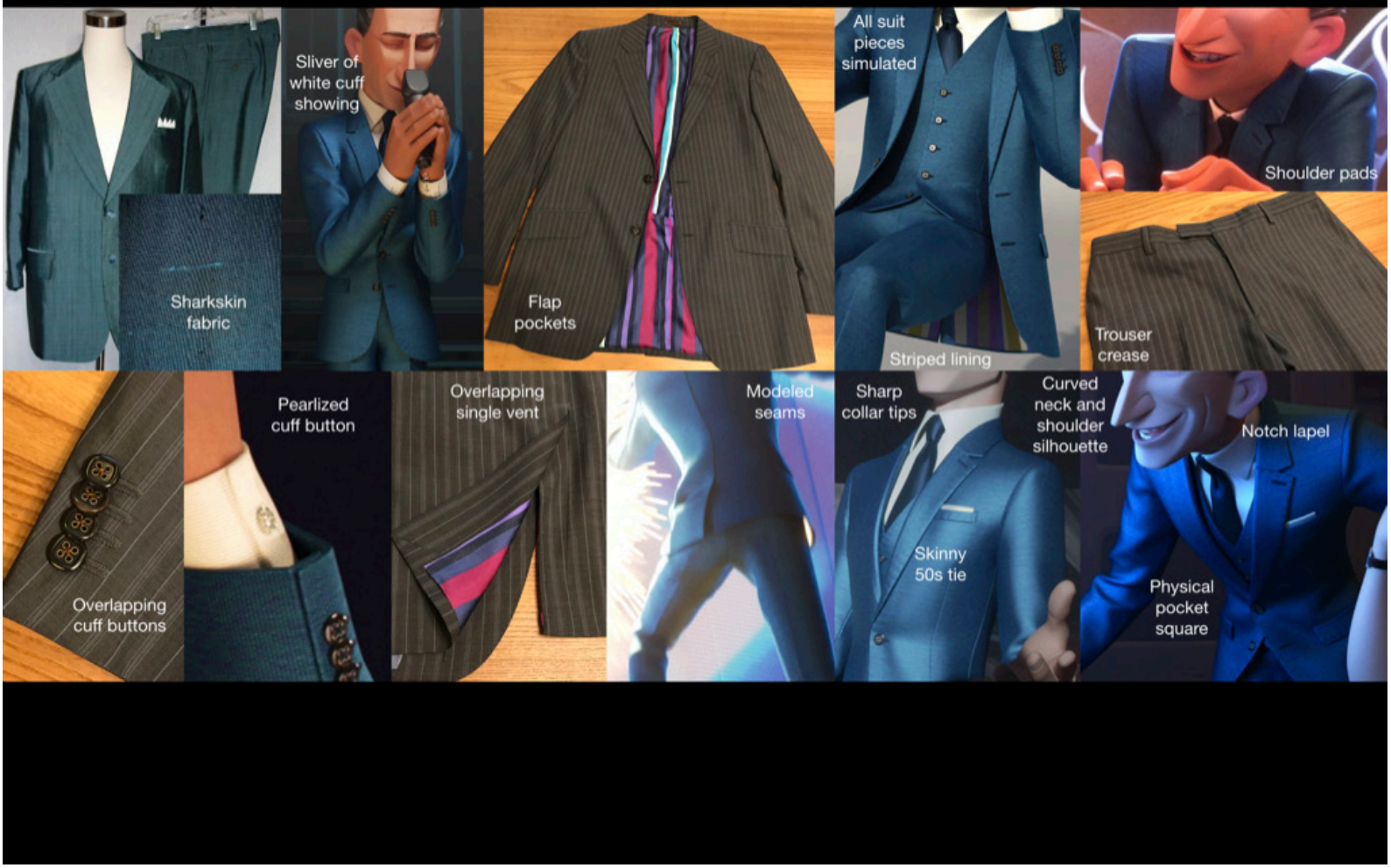


They say it is wiser to invest in a few high-quality garments, rather than buying lots of trendy fast-fashion clothes. On *Incredibles 2*, we aimed for simple garments with bold shapes that could be easily swapped and repeated. Iconic 50s with a modern twist, stylish, yet simple. Each garment was constructed to refit to a multitude of body types, and Shading helped us get even more variation.

Practical Reference

Along with photo reference, we like to look at practical pieces if we can. Here is one of our costume designers Deanna Marsigliese modeling her own outfits. We can see each piece's intended fit, and the tailoring team was able to analyze their constructions closely, feel the weight and movement of the fabric, and take note of where tension and wrinkles naturally occur.

Attention to Detail



Small garment details add a lot to the costume, especially if you want it to look period-specific, culture-specific, or high-end. Tailoring and Shading examined physical reference to learn how suits were constructed and tried to capture the details for Deavor's 3-piece suit.

Translating Reference

- Learning how to look at reference and translate it to stylized characters is an important skill. For costumes, there are three steps:

    1. Get basic construction right. Model all your elements (seams, collar, placket, pockets, zipper, etc.) with the right topology. This can be a one-to-one translation from reference, and just requires attention to detail.

    2. Figure out the proportions of these elements. How big should a polo placket be on Bob? This takes more intuition, but usually these elements should be scaled proportionally to the character's body. Larger and chunkier elements tend to look better in Pixar movies.

    3. Look for fine details of fit and movement - where do we see tension and compression happening in the costume reference? How does it drape? This is this the most difficult step and requires a lot of iteration.

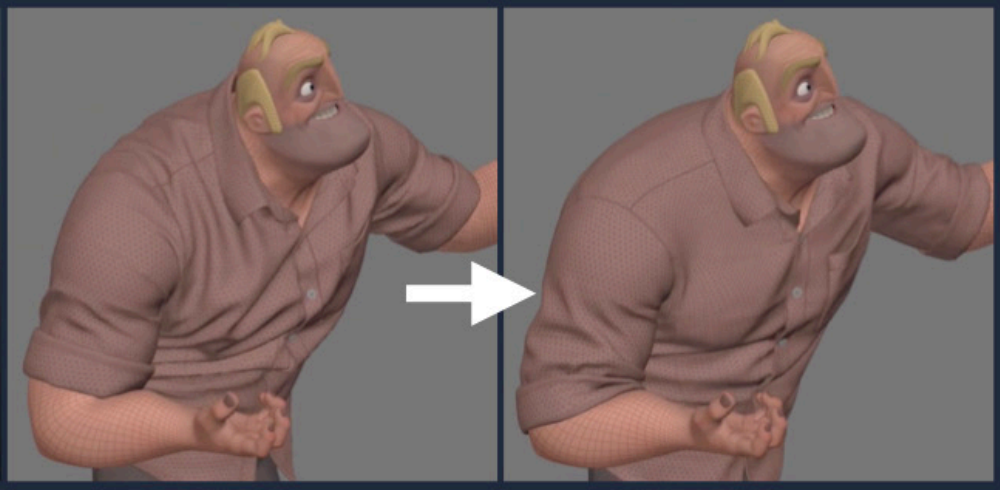
- We can keep learning, both from both real life and other artistic interpretations (2D animation, 3D animation, drawing, and sculpture)

Modeling Garments

At Pixar, we call garment modeling and simulation setup **Tailoring**. We will first go through a quick overview before getting into details. A Tailor's first job is to create a smooth low-res **Input Mesh** in Maya, and tessellate it into the **Sim Mesh** and **Render Mesh**. The sim mesh is typically the flat, simplified, but high-res mesh that gets simulated. The render mesh has thickness and extra details necessary for rendering, and is warped to the sim mesh.

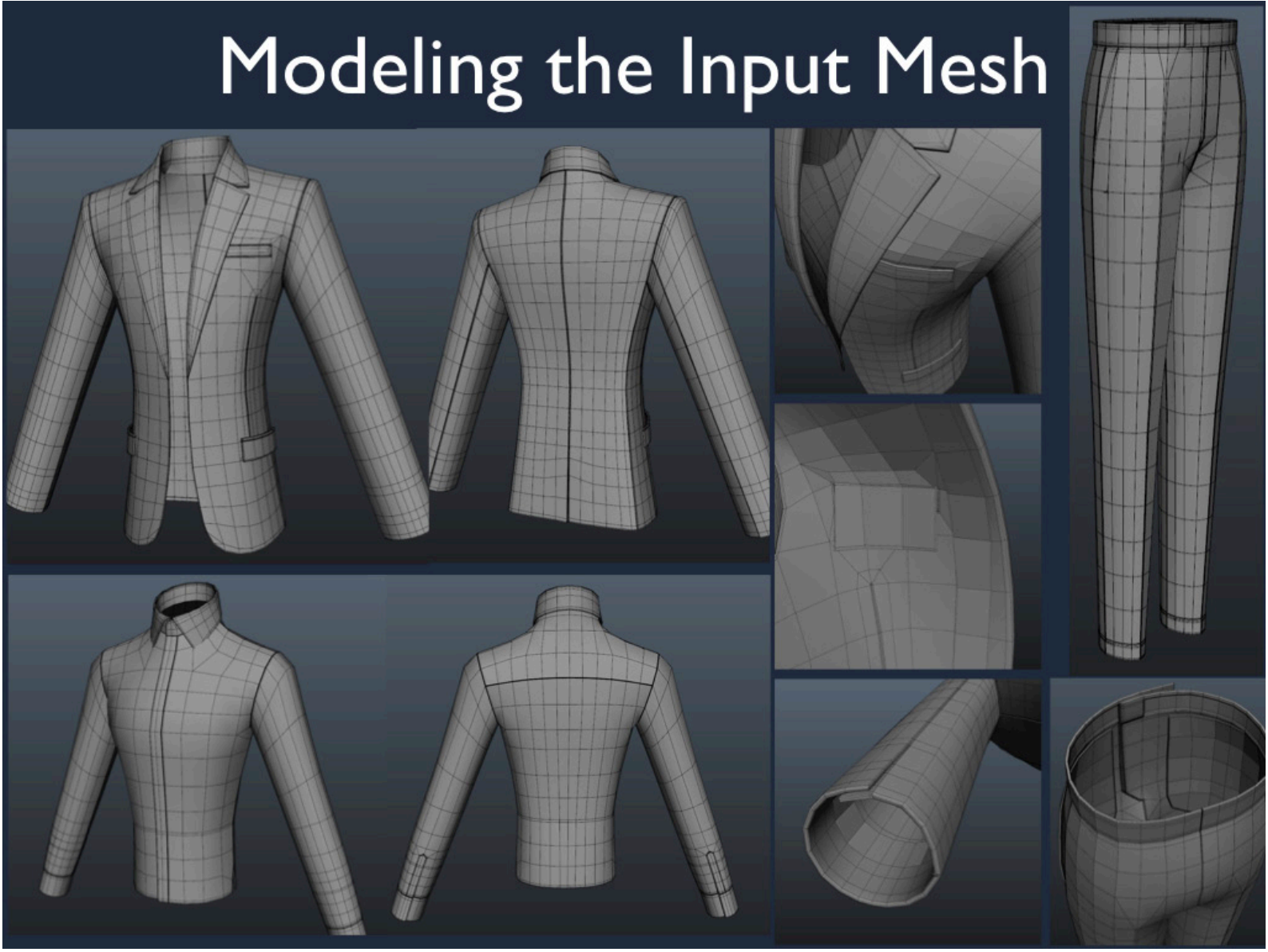
Tailoring Overview

Set up simulation parameters and relax the garment onto the body (note the presence of wrinkles now)



Add additional setup to account for unphysical body deformation, and make the costumes behave better out-of-box in shots

Next, the Tailor needs to set up the simulation parameters, giving the cloth material properties, such as silk, cotton, or wool. This affects how the cloth moves and drapes. We simulate the smoothed garment onto the body so that it folds and stretches over the form. This is called **Relaxing** or **Posing** the garment, and gives the garment a starting state. We then run the simulation in various animated shots to see how it fits and moves with the body animation. We can tweak material parameters and fit, but due to the unphysical nature of cartoon CG animation, we also add additional setup to account for this and improve default simulation performance, or **Out-of-Box Performance**.

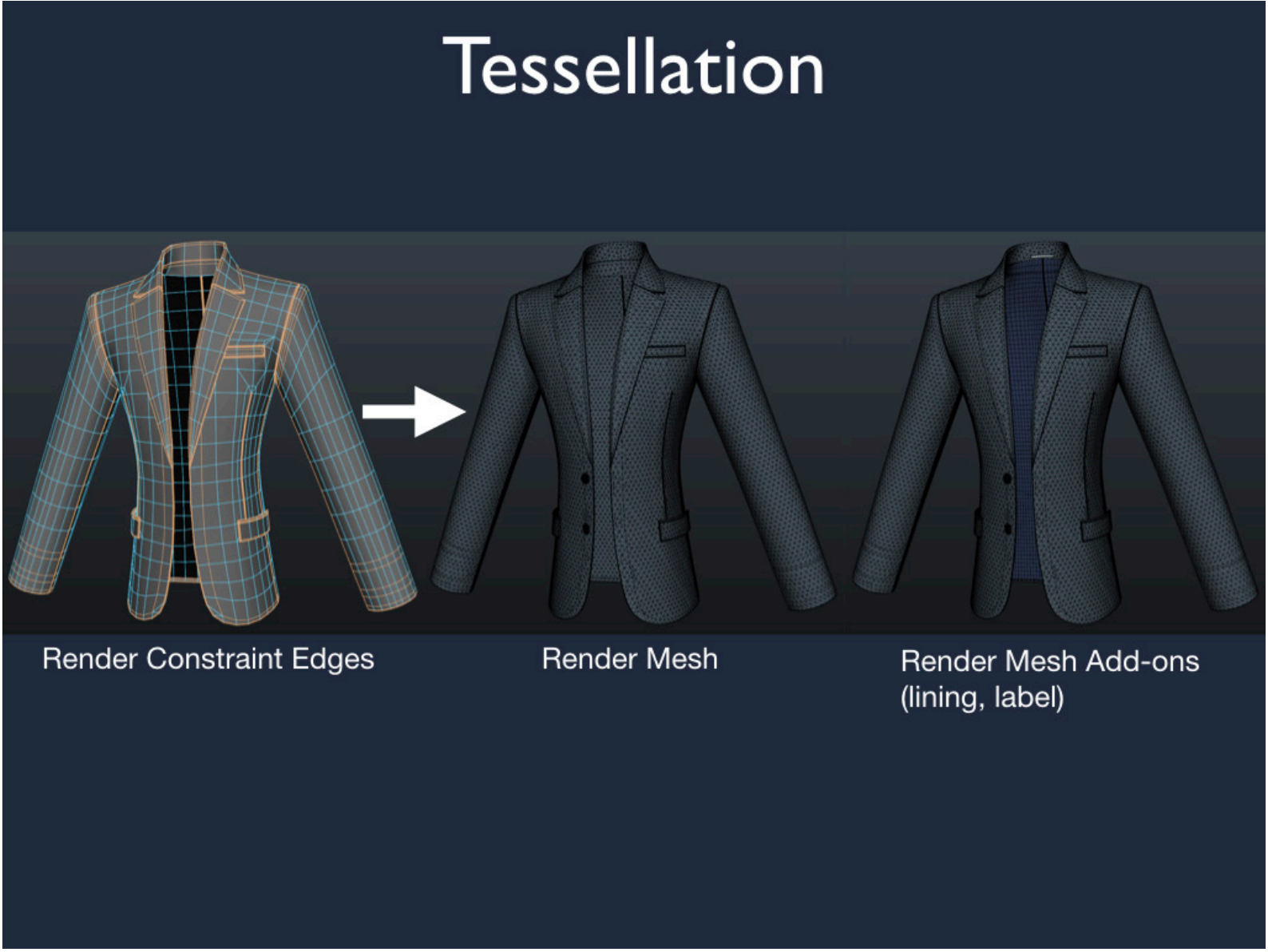


Step 1, Input Mesh:

During the modeling stage, Tailors work in Maya, and we use a 3D tailoring workflow. For the Input Mesh, we model low-res smooth quad meshes, with seam details and foldover thickness. We build in physical details like pockets, cuffs, and vents. Eventually, we will define all regional material properties on the Input Mesh as well, which get transferred to the Sim Mesh automatically.

Step 2: Sim Mesh Tessellation

Our simulator can only work with **triangle meshes**, and needs enough resolution to capture small fold details. We must turn our low-res Input Mesh into a high-res triangulated Sim Mesh and Render Mesh. This process is called **Tessellation**. For the Sim Mesh, we first tag edges and faces to be deleted, generating a simplified **Decimated Mesh**. This typically has a single thickness and no details like seams. This gets tessellated into the Sim Mesh, using the **Constraint Edges** as tessellation constraints.



Step 3: Render Mesh Tessellation

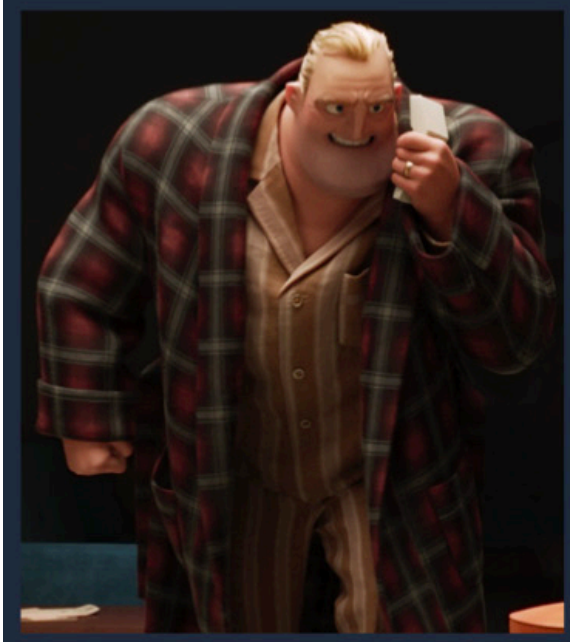
We also tag constraint edges for the Render Mesh, and tessellate the Input Mesh directly. By using the same Input Mesh to generate both the Sim and Render Meshes, we ensure that they stay in sync with each other when we want to make tailoring changes. We then warp the Render Mesh to the Sim Mesh. We can also model extra details like pockets and lining that aren't simmed, but get warped as rendered geometry.

Note: Our tessellator uses hexagonal tessellation because this works well with the Loop subdivision scheme. As we move to Catmull-Clark subdivision, we are also considering Delaunay triangulation for the Sim Mesh, and Quads for the Render Mesh.

In real life, garments are tailored with 2D flat cloth panels and sewn together. There are 3rd party software packages made for emulating this workflow in CG. **2D Tailoring** usually gives you a more realistic look, because you can't introduce unnatural curvature, and folds will happen where they would in reality. We do not have a 2D pipeline at Pixar, but we can apply similar flat-panel construction techniques with a hybrid 2D/3D approach.

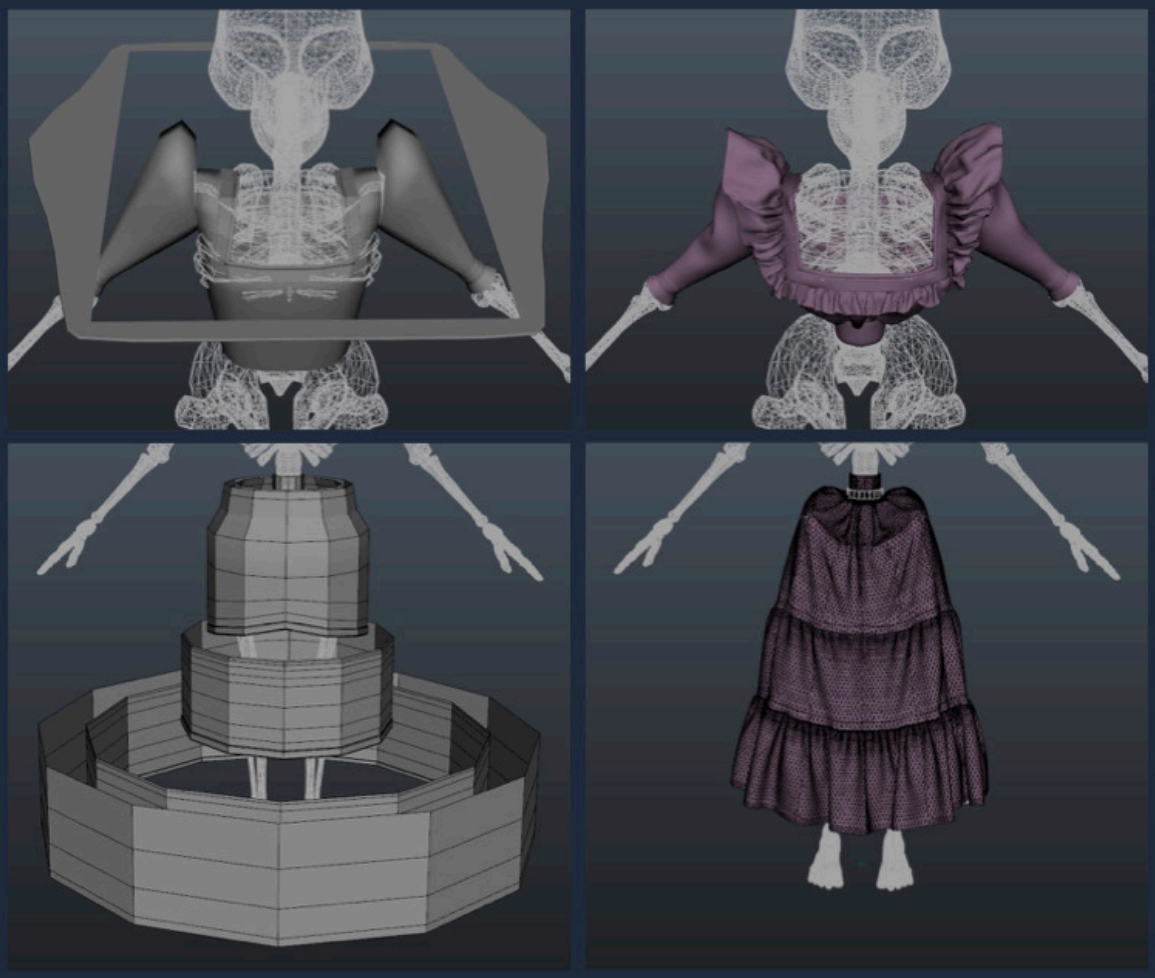
To do this, we model the Input Mesh as flat and smooth as possible. This means some panels need to be separated, such as the robe lapel. We can sew these back together with a technique called **Gathering**. While 2D tailoring is more realistic, it is often helpful and efficient to be able to model art-directed shapes in 3D, such as Underminer's cape, and the 3D curvature of Bob's chest.

Hybrid 2D/3D Construction

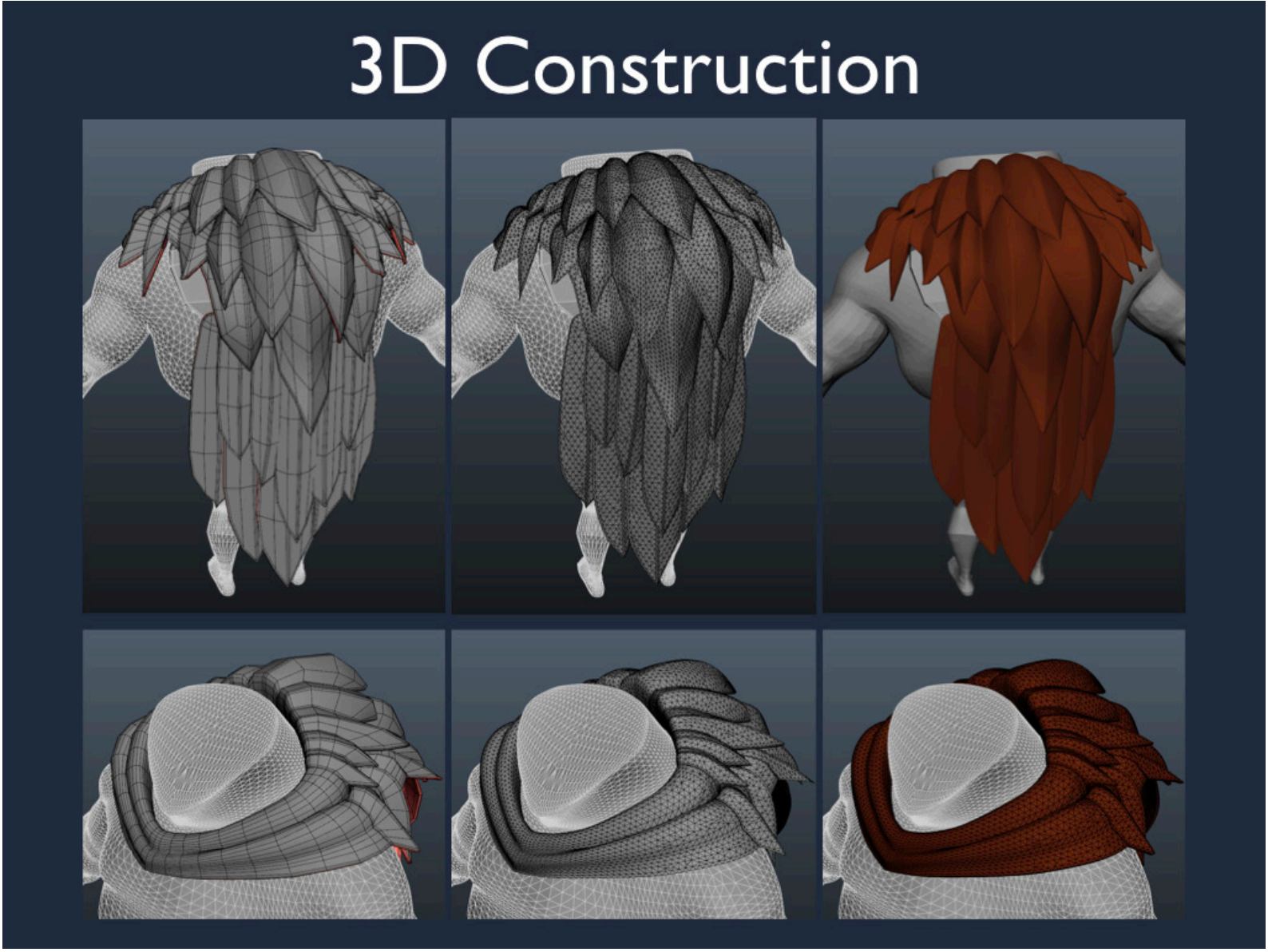


Here is what these garments look like after simulation.

Hybrid 2D/3D Construction



On *Coco*, we had a lot of ruffles and gathered folds. Here you can see how the flat Input Mesh is modeled. The size of the ruffle panels determine how many folds there will be.



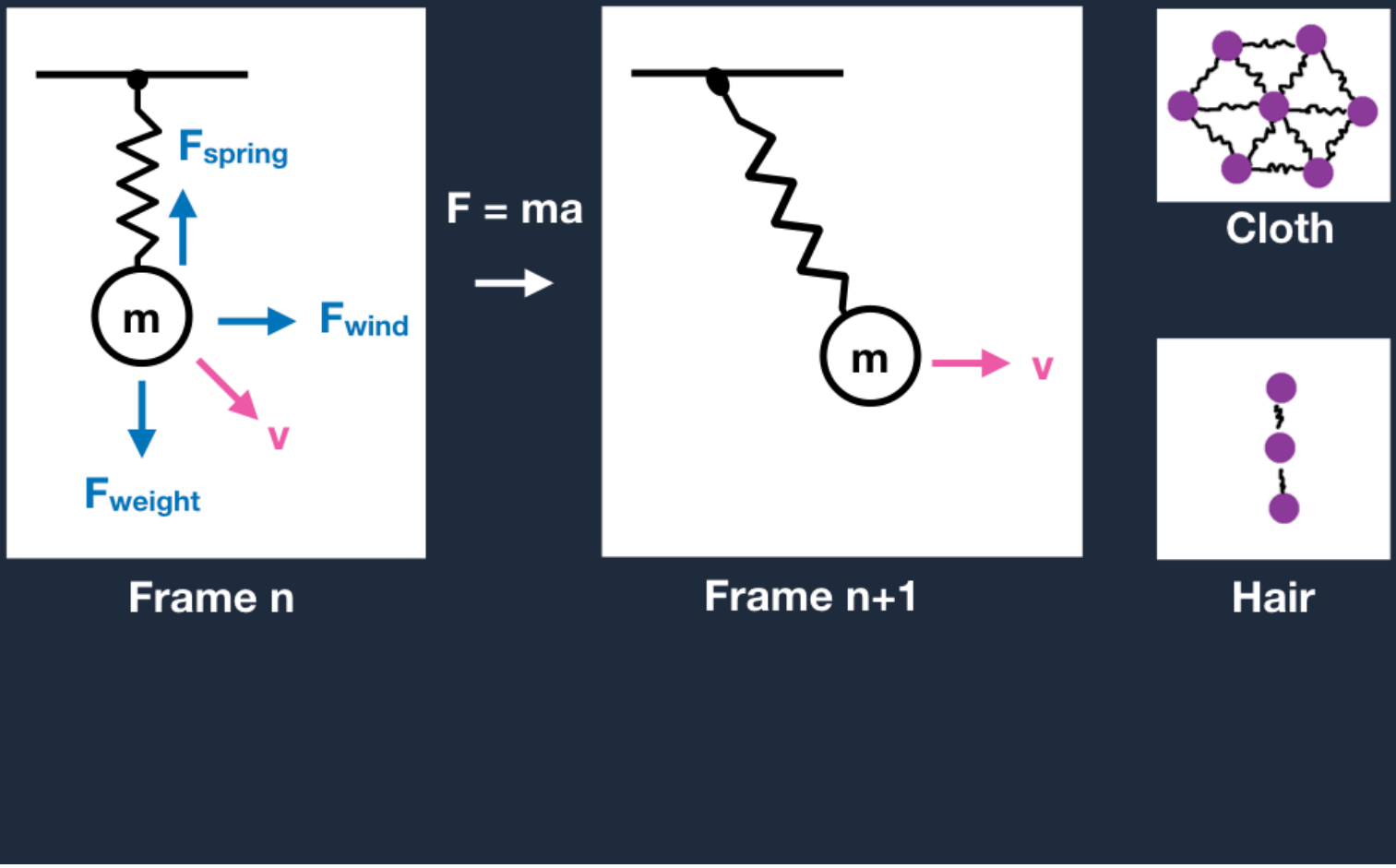
Screech's cape is an example where **3D Tailoring** is beneficial. It would be very difficult to model something like this with flat panels and sew them together. There are a lot of unnatural shapes and curvature and unusual construction. With Screech, we needed to interpret the art and mock up look tests quickly, so being able to model this Input Mesh, tessellate it, and simulate it right away saved on iteration time.

3D Tailoring: Pros and Cons

- Pros
    - We are able to model complex shapes easily without 2D construction (high curvature areas are more intuitive)
    - Sim and Render meshes stay in sync when we make changes
    - All weighted sets are transferred automatically
    - It is historically easier to find people who know how to model and teach them how to make clothes (most people don't know flat paneling)
- Cons
    - Flat paneling is not intuitive in 3D cloth
    - Harder to use traditional fitting and tailoring techniques
    - Not as fast to prototype as 2D tailoring software (tessellation is not interactive)
    - Because it's proprietary, it's difficult to train new people

Simulation Setup

Simulation Overview



On a basic level, simulation involves knowing the position and velocity of a particle, and the forces acting on it at a given time. Using F=ma, we can calculate the new position and velocity of the particle at the next time step (Integration). For a particle hanging on a spring, there will be a force acting along the spring, with the direction depending on whether it is stretched or compressed. (Hooke's Law F=-kx) You might also have external forces such as weight from gravity, collisions, air resistance, wind, etc. A cloth is basically a large grid of particles connected by springs. The Simulator will take all of the positions and velocities into account and figure out where the particles will be next.

Fizt, Our Simulator

- Based on work done by David Baraff, Andrew Witkin, and Michael Kass
- Speed, performance, and collision response updated more recently for "Coco" by David Eberle
- Implicit backward Euler solver - choice between first or second order approximation (second order looks less damped)
- Robust collisions with Continuous Collision Detection and Global Intersection Analysis
- Many features and well-tested in production
- Usually between 4 to 20 seconds per frame simulation time

https://www.cs.cmu.edu/~baraff/papers/sig98.pdf
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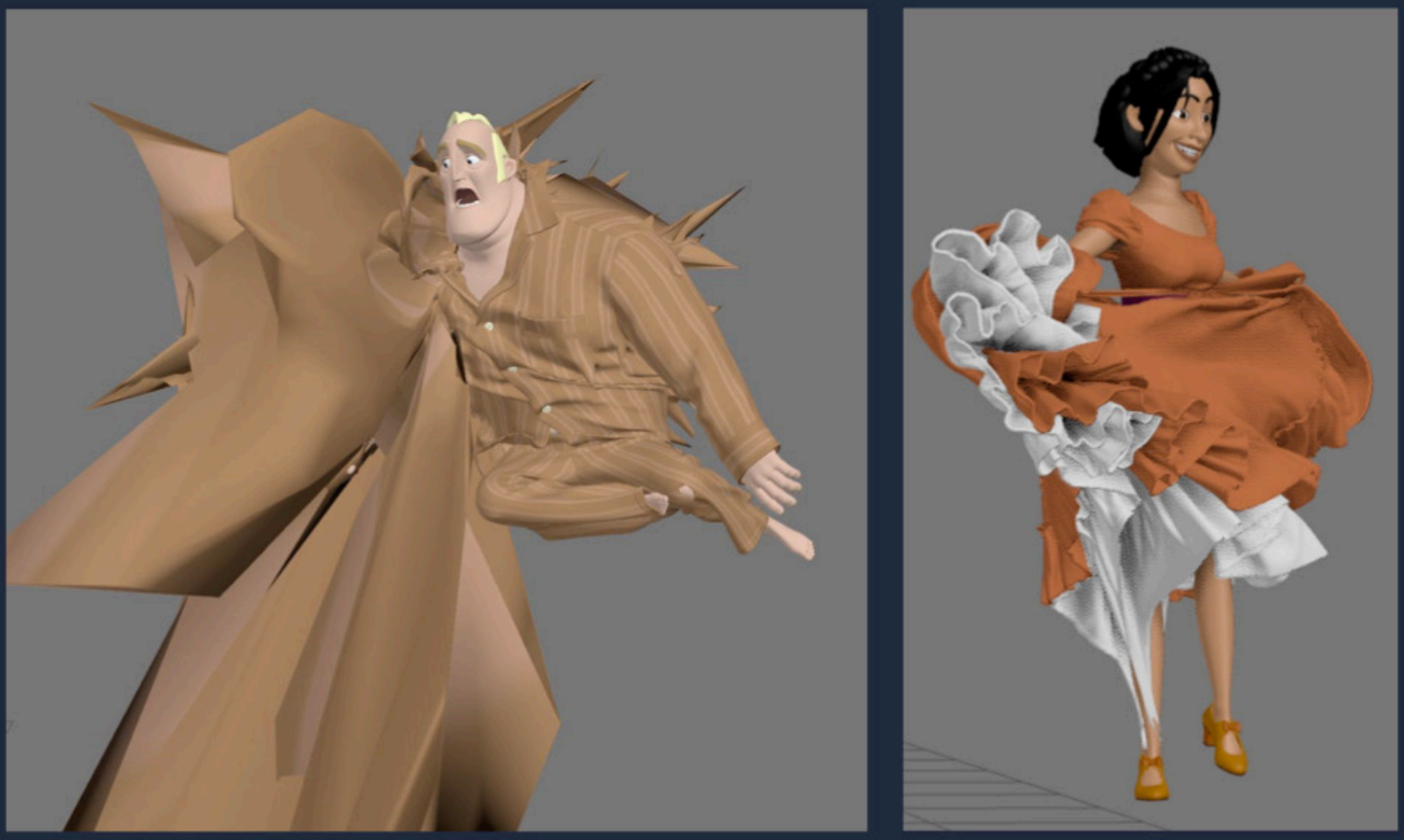
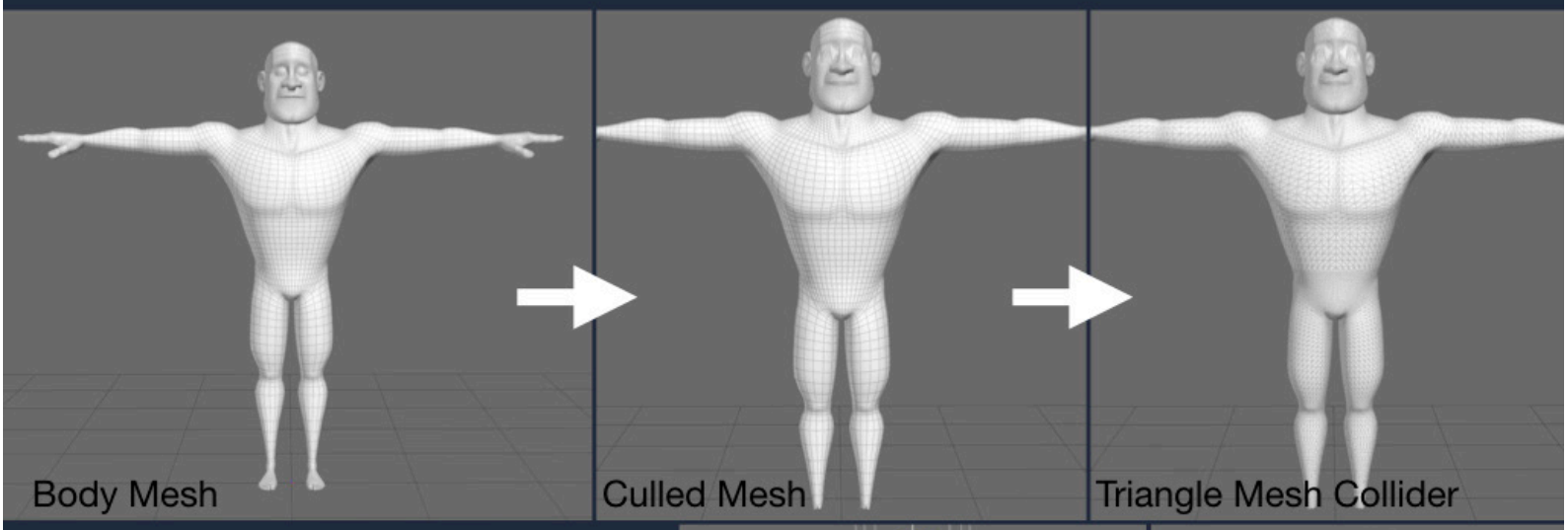
Sim Stability

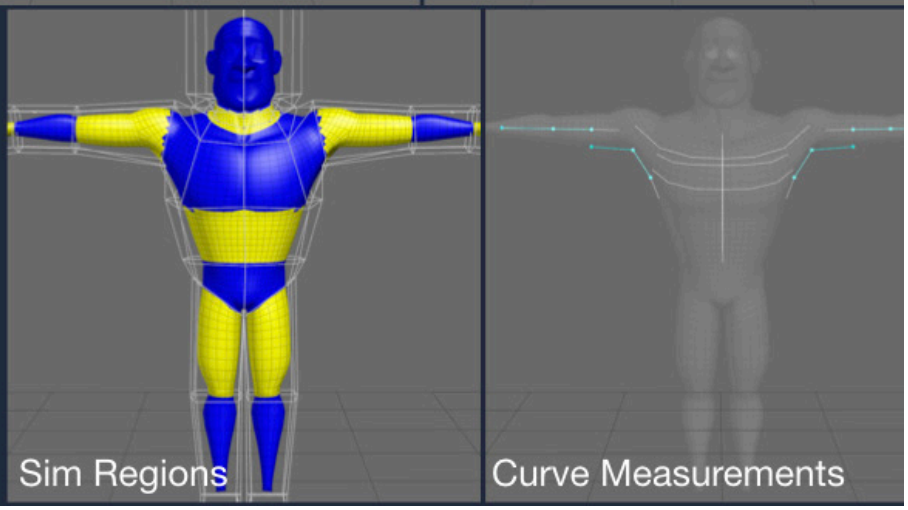


This is what it looks like when a sim explodes or snags. This sim was run on extreme blocking animation and Bob's cuff got caught in his finger. The dancer's dress got snagged on her foot. Because of the improvements in our cloth simulator collisions, thankfully this doesn't happen much anymore. But it's still possible, and we try to do what we can to prevent it. Sims can also become unstable in a more subtle way, such as jittering and popping when caught in tight spaces, and oozing from the simulator failing to fully converge. When talking about **Sim Stability** during the next two sections, this is what we're trying to prevent.

The Collision Body



1. Start with body mesh
2. Cull out eyes, mouth, and other regions (like feet)
3. Triangulate the mesh with different levels of refinement for the Collision Body
4. Set up body regions for easy access during cloth sim
5. Add curves to measure body lengths and angles for dynamic cloth scaling



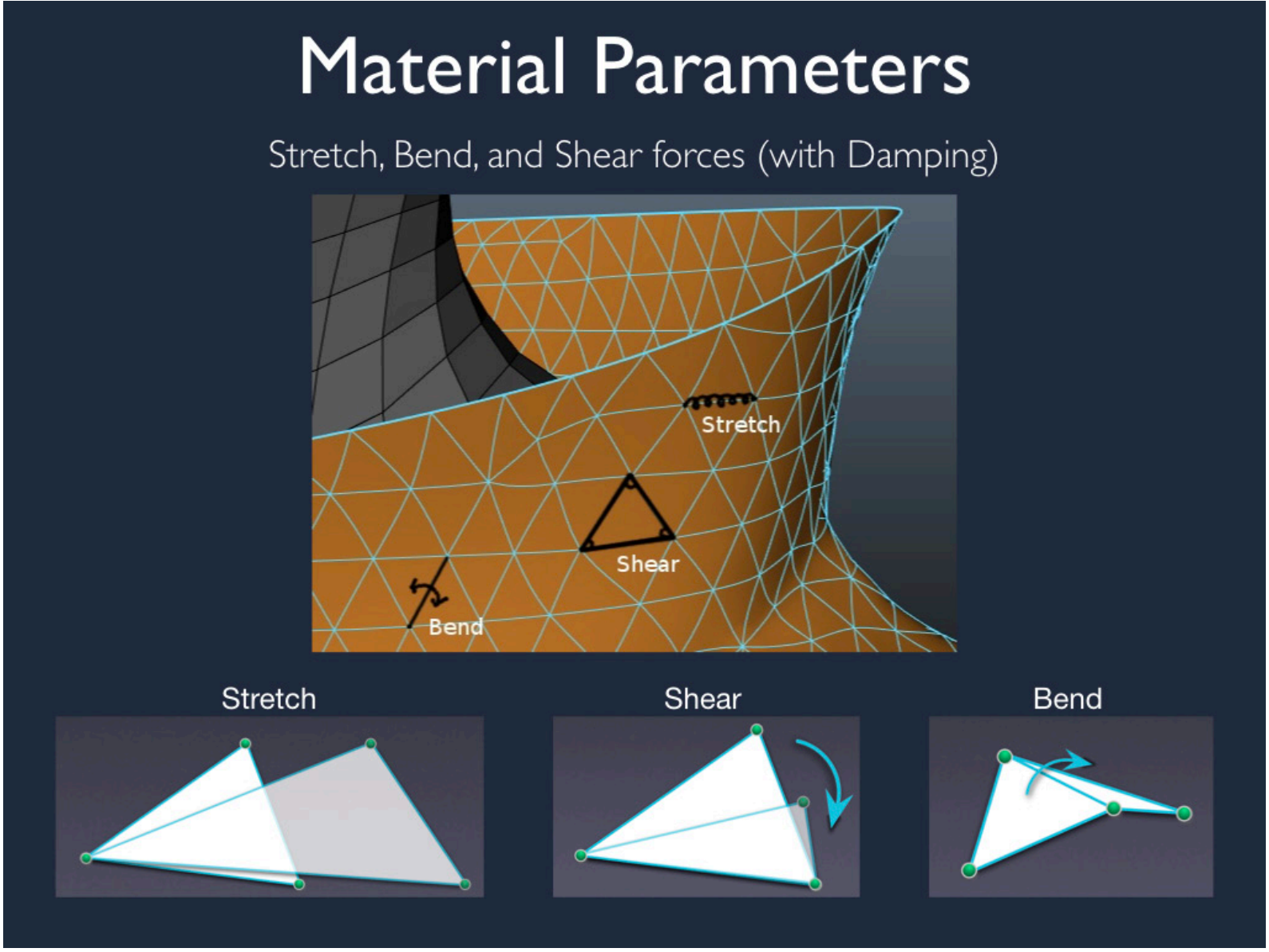
The **Collision Body** setup is an important step in our process. It is a separate mesh that is copied from the character's body mesh. We can cull out the eyes, mouth, and other regions such as feet, simplifying our body, and allowing less opportunity for snags in tight areas. We triangulate this mesh, and because our character models are often low-res, we have to increase the subdivisions by one or two times. We also tag body regions such as Chest, LUpperArm, Neck, etc. by placing a lattice around the body. This allows us to access these areas in the cloth simulation. There are also occasions when we'll want to measure lengths of the body. We attach curves to it that can calculate difference in length between posed and rest. The collision body is known as a **Kinematic Object**. Cloth is a **Dynamic Object**.

The Collision Body

Body Mesh | Modeled Collision Geometry | Collision Body

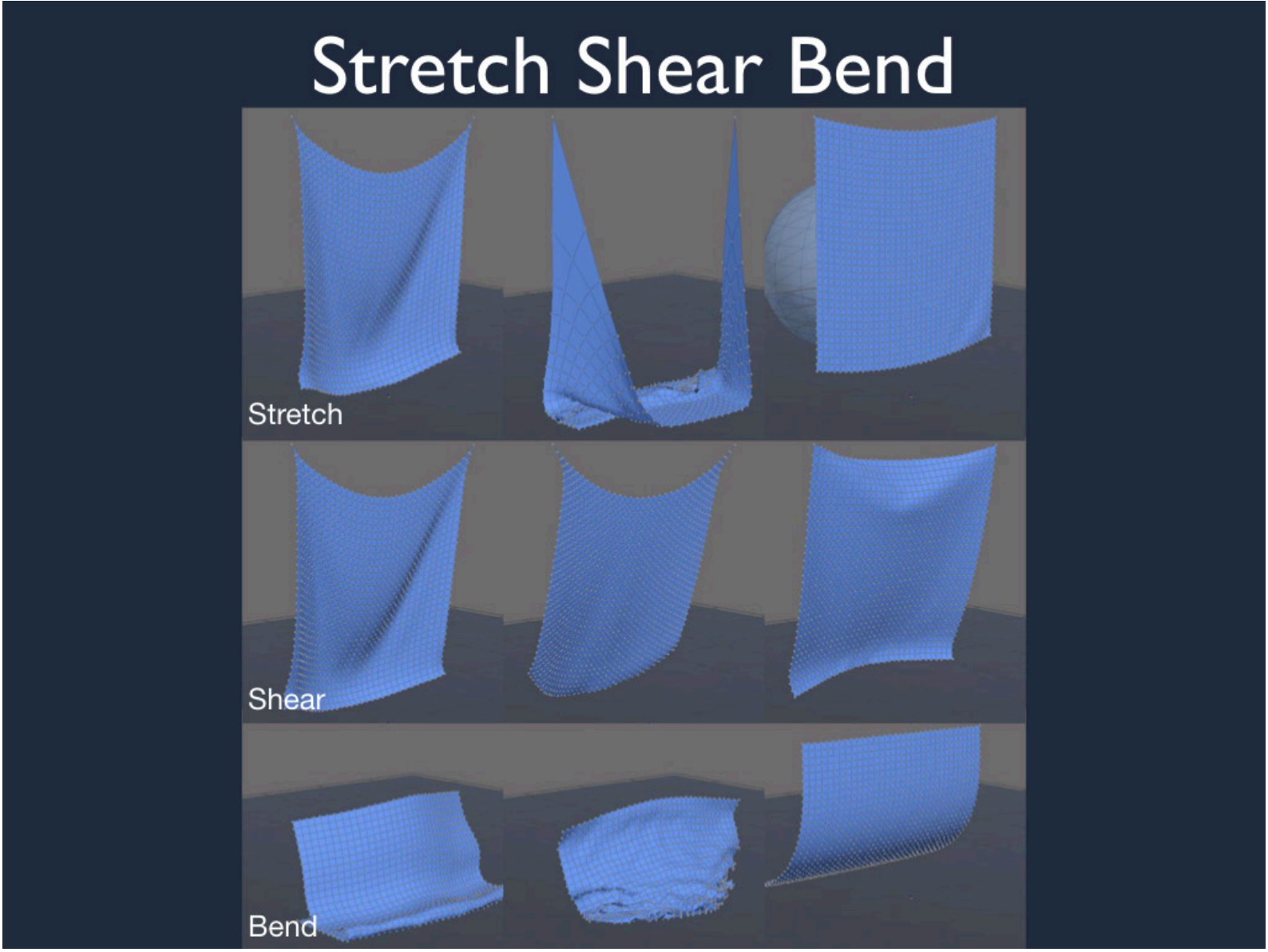
We can also model simplified collision geometry that attaches to the body mesh for more sim stability

Sometimes we model simplified collision geometry if we can get away with it. On *Coco*, we fused the arm bones and rib cage, allowing enough detail to show through the cloth, but preventing bad snags in between bones.

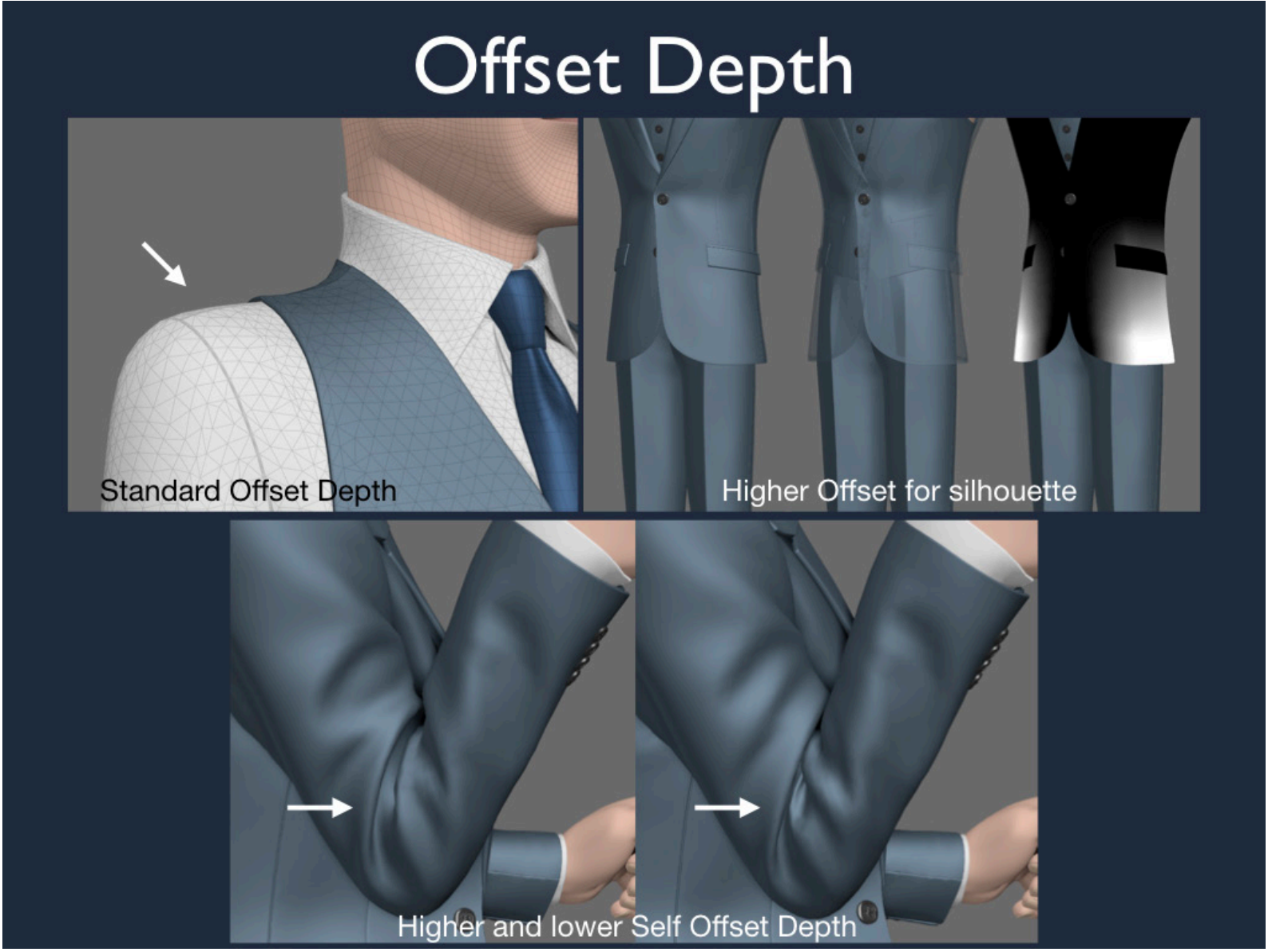


The three internal forces for cloth are **Stretch**, **Bend**, and **Shear**.

Stretch is the spring along each of the triangle edges, and its stiffness determines how easily the edge length can change. Shear is the resistance to changing the interior angles of the cloth triangles, similar to the bias stretch of real cloth. Bend is the resistance to bending between triangles along their shared edge, and the radius of curvature can be set for wider or tighter folds.



Here are some wedges of different values for Stretch, Shear, and Bend. With these three forces, you can achieve a wide variety of cloth looks, such as Silk, Leather, Cotton, Wool, and more. The values of these forces depend on your simulator.



Offset Depth is the distance one garment will maintain when colliding with another garment. If it is 0, the two cloths will directly touch in a collision, but we make it a small value to allow for the cloth's thickness. Deavor's vest rests slightly above his shirt in the first image. We increase the depth for thicker cloths, or to create a silhouette. Deavor's body is very skinny, and a jacket would normally hang straight down. But we wanted it to flare out at the bottom, so we increased the offset depth x3 at the bottom, and had a smooth falloff back to normal at the waist.

Self Offset Depth is the distance a cloth will maintain when colliding with itself. On Deavor's sleeve, you see the difference between a high depth and a low depth when he bends his arm. With the high depth, there's an unnatural gap, and with the low depth, the cloth can contact itself. However, sometimes we keep a higher depth for stability.

Friction

Tangential Damping “friction” between shirt and pants

Shape Friction for starched shirt

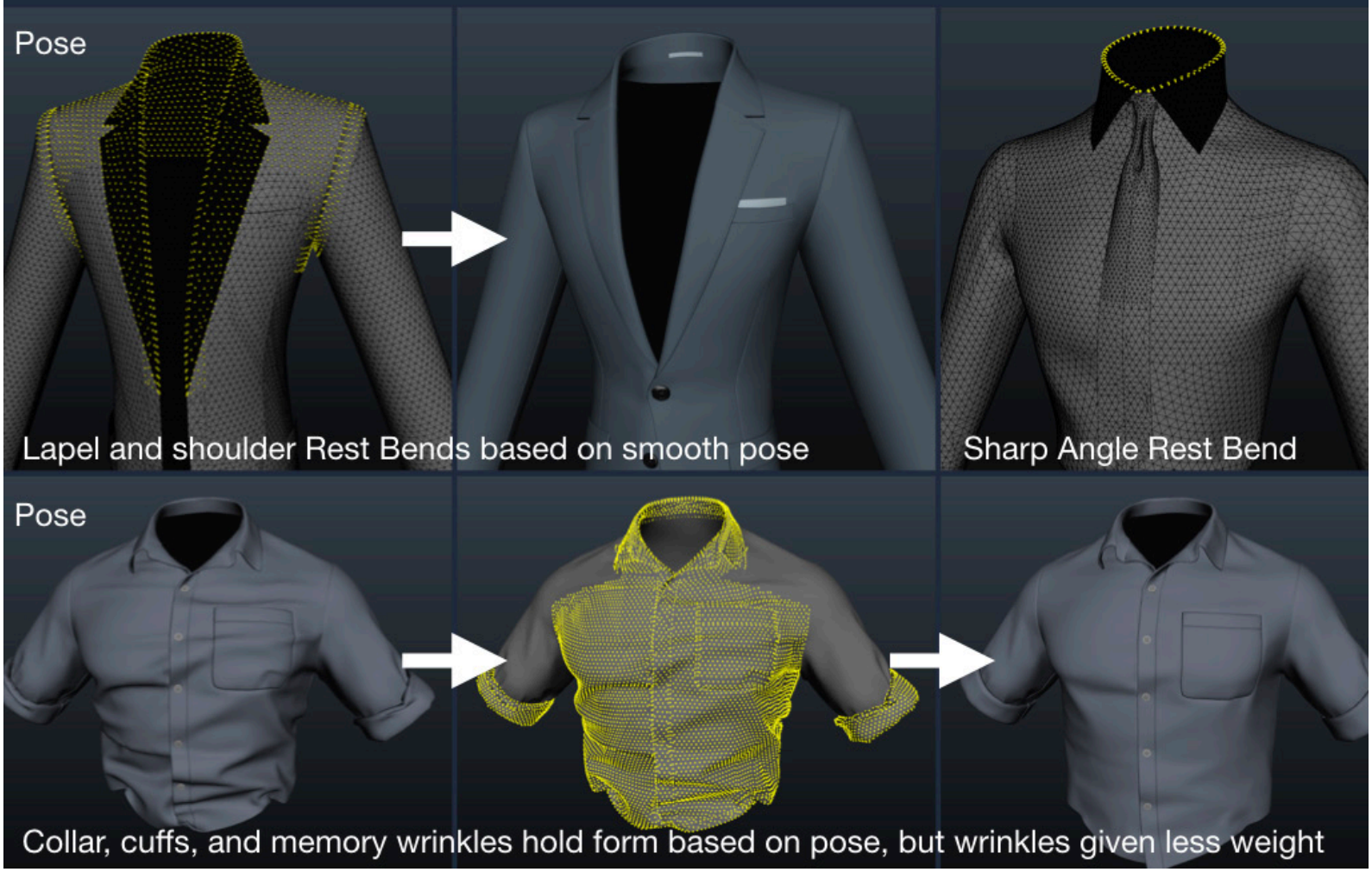
Friction is still a problem in cloth simulation, and we don’t have a physical solution yet. We have cheats and approximations, but things like cloth-to-cloth static friction (which is what prevents jackets from sliding off) are not solved yet.

Tangential Damping is essentially cloth-to-cloth dynamic friction, and adds resistance to sliding. On Helen’s pajamas, you can see the nice pull of the cloth that comes from twisting her upper body, but having the shirt bottom catch on the pants. However, it is not static friction, and if you freeze this pose, the cloth will slowly slide and untwist. We often use Glues to prevent this in shots.

Slide & Stick Friction are cloth-to-collisionbody frictions, causing sticking and resistance to sliding between the cloth and a kinematic object.

Shape Friction is not technically “friction”, but is used to freeze the cloth when it gets sufficiently slow by imparting a force on the points to maintain the current shape. You can set the amount of speed and distance it takes to get the points to move again. This is useful for making starched shirts, holding stiff shapes, and preventing oozing in shots.

Rest Bends



In real life, when you iron your clothes, or bend them repeatedly in places like knees and elbows, they can hold a certain crease or shape.

In CG we achieve this with **Rest Bends**. These set the default angle between triangles, so that if you make the cloth stiffer and less bendy, it will hold the angle without flattening out. We can set the bend angle for edges manually, or based on a pose. This is useful for collars, lapels, memory wrinkles, cuffs, etc. For cases like memory wrinkles, we can reduce how much the pose affects the angle with a weight value. This is great for preventing perfect CG symmetry and smoothness.

Other Parameters

Normal Acceleration is a force that pushes points in the direction of their normals. We can use it to pull cloth inwards to look wet, reveal extra skeleton form, or highlight the body contours in a supersuit. We can use it to push out for Jack-Jack's foam supersuit effect, puffy pillows, and shoulder pads.

Density is the cloth mass per unit area. It can be adjusted to make the cloth heavier or lighter. For Underminer's heavy leather cape, we increased density.

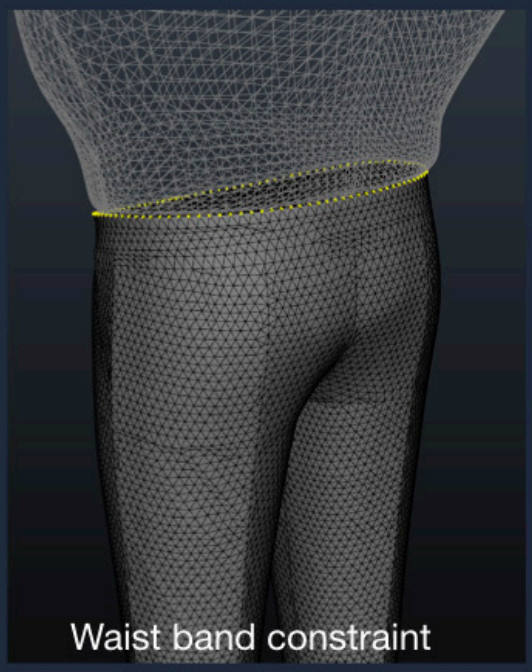
Gravity can sometimes be changed for similar effects. Increasing gravity will make cloth feel heavier in the downward direction, and we often use this on heavy coats or robes. You can also remove gravity for weightless or underwater looks.

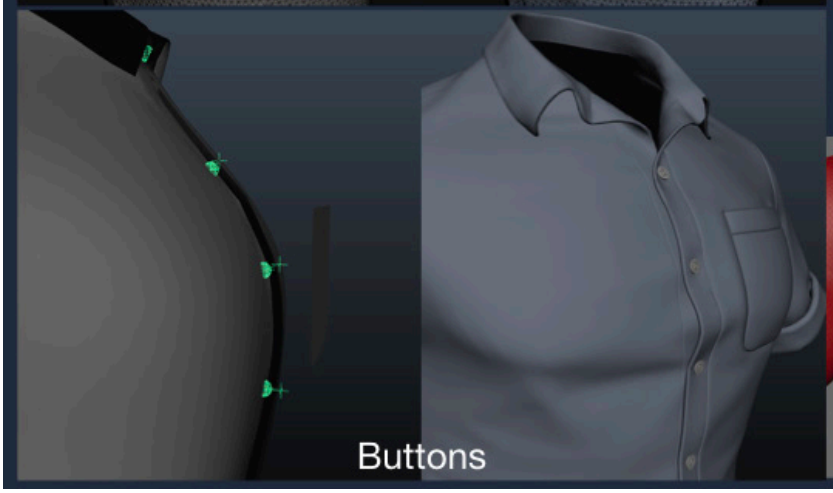
Airdrag is turned off by default, but we turn it on if we want our cloth to blow in the wind.

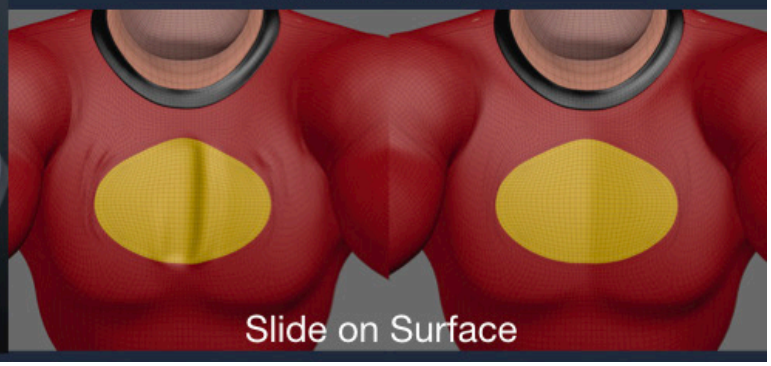
Drag is a velocity-based force that resists movement in world space. It typically looks unphysical, but can be used for underwater looks, or to slow something down for a stylized effect.

Kindrag is a velocity-based force that resists movement relative to the Kinematic Points (the cloth rig). We use this to prevent excess movement in a shot, or on the bottom of heavy coats, such as Evelyn's.

Springs and Constraints







We have a wide variety of additional springs and constraints we can add to the cloth, in addition to the internal cloth properties.

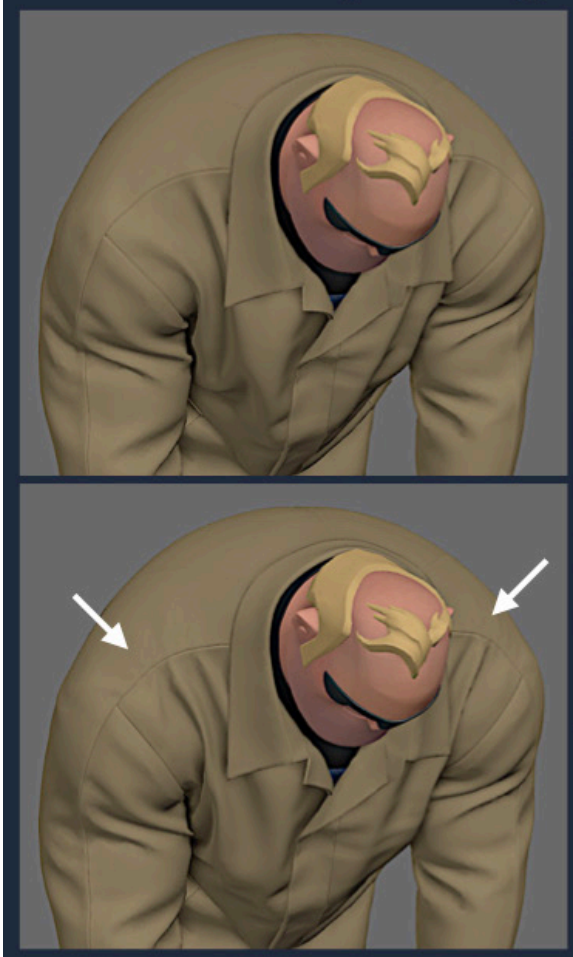
Curve Attaches - We can attach two pieces of cloth together with “to” and “from” CV curves that are placed where you want the attachment to happen. This is often used for pockets or to hold plackets shut.

Cloth to Collbody Glues/Constraints - We can attach cloth to the collision body - a Hard Constraint will lock the points and follow the body completely, and a Glue will target the same position with a soft spring. We often use Constraints for pants/skirt waistbands and tucked in shirts. We tend to use Glues to approximate static friction, such as keeping collars up, or preventing jackets from sliding off the body. But this is unphysical and causes problems in shots. We explore a better method than Glue in the “Improving Out-of-Box Performance” section.

Buttons - Springs that attach a point on the cloth to a different point on the cloth. We can expand the radius of influence to act on several points as well. We use this to hold cloth together at a point (usually for buttons), but there could be other creative uses for this spring.

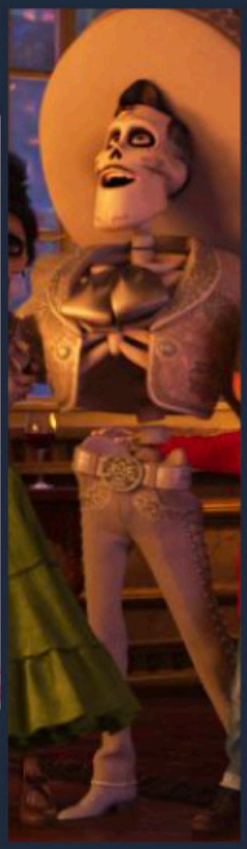
Slide on Surface Constraint - This is used to constrain cloth to the surface of the collision body, but allow it to slide. It can be a hard or soft constraint. Bob’s supersuit logo area would pucker in unappealing ways under high compression forces. It looked better to keep it locked to the surface. It was also used on the back of knees to force a crease to happen when the knee was bent a certain angle.

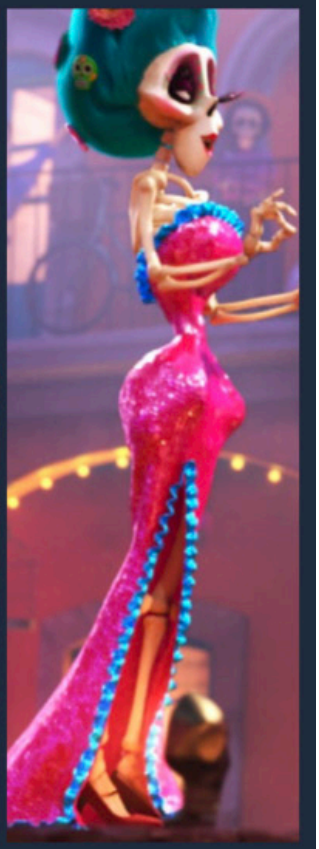
Springs and Constraints



Adding Seam Springs on shoulders

Cloth-to-Cloth Glue on apron, bow, and scarf





Limit springs holding jacket shape and preventing dress slit from separating past a certain distance

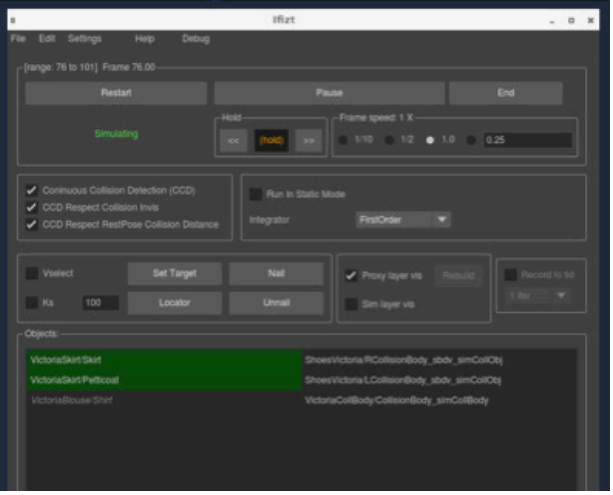
Seam Springs try to emulate stitching, tension, and rigidity introduced into garments along seams. Springs are formed between alternating vertices along the edge, pulling them together. This creates a few extra folds and puckering along Bob's shoulders. We try to use these on most seams, especially for stiff jackets, shirts, and pants. Note: we also paint a lot of seam wrinkles in Shading, so we don't always do this in the sim.

Cloth-to-Cloth Glue glues cloths together. We often use it for attaching cloths, such as Rosita's bow to apron, and apron to dress, or trying to mimic friction, such as between her scarf and dress.

Limit Springs can prevent a set of cloth vertices from getting closer than a certain distance to a set of cloth faces. It can also prevent them from separating past a certain distance. We needed Ernesto's jacket to keep its form, but he doesn't have much of a body under there to support it. We used Limit Springs to prevent the jacket sides from expanding open, and to prevent the bottom edge from collapsing inward. We also used it on the MC's dress slit, so that it didn't open too much and become too revealing.

Relaxing and Draping Garments

- Relax garments onto body in Maya with iFizt, our interactive version of Fizt (same features and code)
- Pull points around while simulating to get a nice start pose
- Easily find jitter and instabilities and fix in posing or by changing parameters
- Export and save poses of the garment

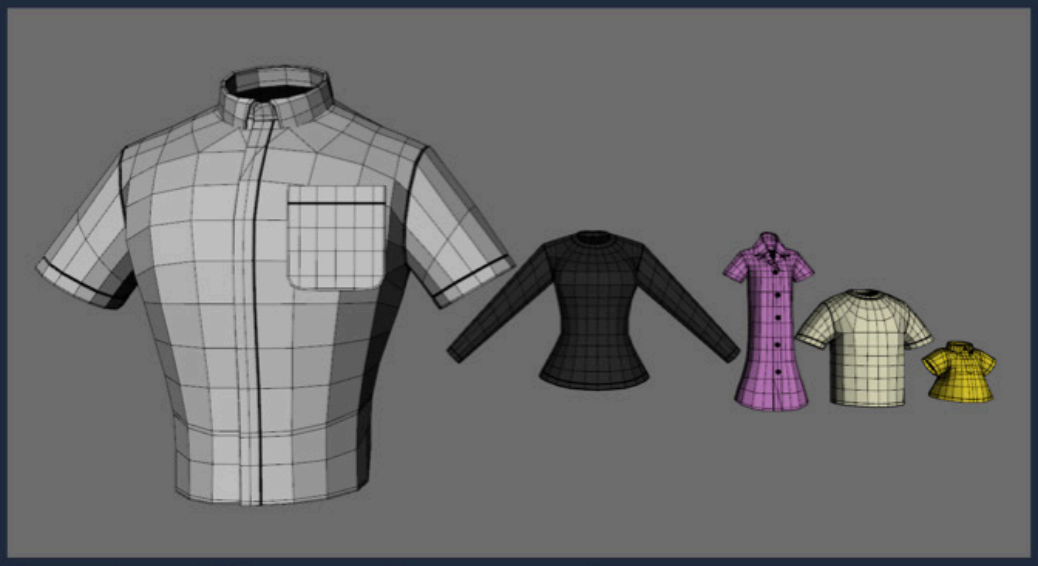


To achieve a good start pose on the cloth, we must simulate the smooth flat-panel tailored outfit onto the body. We typically do this with the arms down at a 45 degree angle. We have a realtime version of our simulator in Maya called “iFizt” that lets us interactively pull cloth around to get a nice drape. We can also interactively change material parameters to see how they affect the drape, fit, and fold size.

Relaxing and Draping Garments

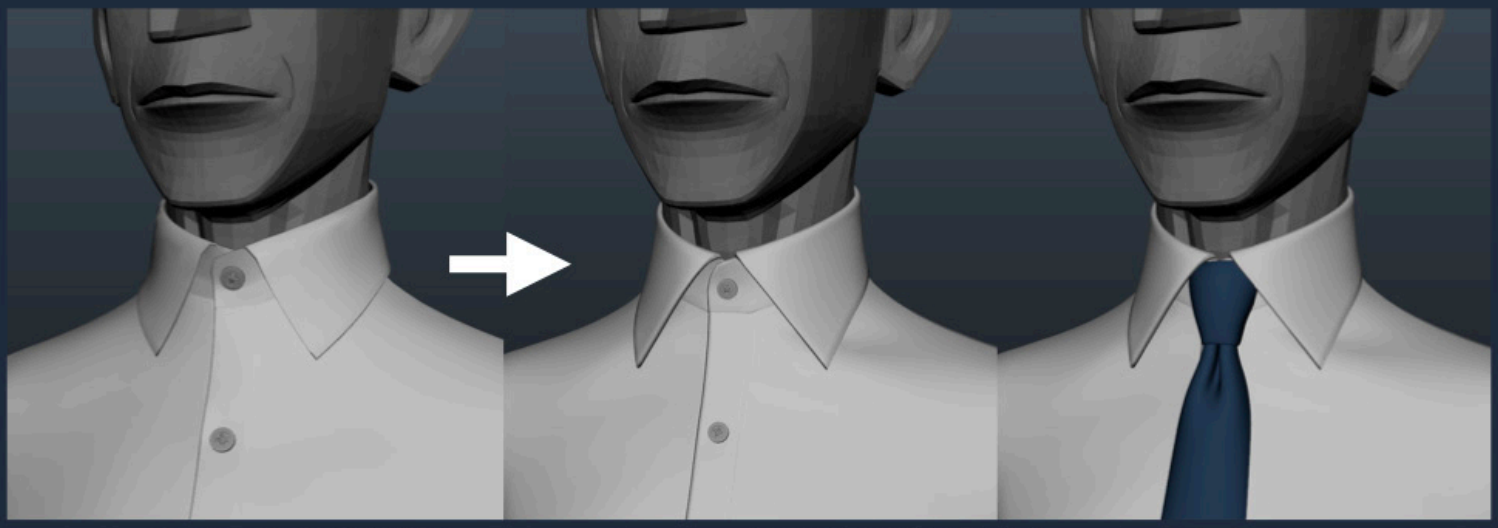
We can drape complex cloth poses, such as Tia Rosita's scarf. We start out with the flat panel, and tie a knot, then simulate it onto the body, pulling the cloth around until the folds look appealing. If there are instabilities and jitter in the knot, we can isolate and fix those by pulling cloth and finding penetrations. We can save out different poses of the cloth for different start poses.

Context



When setting up sim parameters, it is important to keep context in mind, especially for characters with very different scales and body types that will be on screen together. Make sure fold size, proportions of collars and trims, and more, all fit in the same world. Put your characters next to each other early.

What to Watch Out For



Here are a few examples of what to look out for when tailoring.

For Deavor's collar, our first pass lacked the sharpness of the original design. It caved in on the sides, floated off the collision body, the tips didn't have a nice angle, and the V in front where the collar meets the placket was a little too separated. We took a close look at how sharp collars and ties sit and adjusted the shape for a huge improvement.

For this purple shirt, we noticed it floating above the shoulders and flaring far from the neck. This is partially due to the unphysical 3D construction. We need to model collars as close to 2D as we can to get them to sit right. In general, to open the collar up, we want it to roll open instead of stretch open. We also want it to contact the neck in the back and sides, and we want the collar tips to touch the chest.

We also tend to model our collars too low on the back of the neck. From the side view, the line is usually more appealing if it is a smoother curve from the back collar to the chest. This means pulling the collars up.

What to Watch Out For

For the top shirt (Helen's pajamas) our first pass was modeled too close to the form of her body, such that when simulated, no natural folds happened in the drape. This is one of the dangers of 3D tailoring. We actually like a bit of draping off the bust, so we loosened the shirt and tried to make it more 2D. We also fixed the floating collar.

For the bottom shirt (Evelyn's shirt), with our first pass, the drape didn't sit right. It caught on her hips and pushed up the fabric, creating a V shaped fold at her waist. We wanted the material to feel like a rayon cotton shirt with an easy drape - not too wrinkly. We relaxed the fit and made it wider so it could hang down smoothly. We also widened the sleeves to get a looser fit with bunching just at the bottom.

We need to pay attention to the crotch and knee folds in pants. These can get unappealing quickly. For Bob's crotch, we had to iterate on fit and introduce autoscaling to control the size of the wrinkle. It can't be too tight or too baggy. We actually needed to build in an edge with weaker bends that the pants would tend to always crease on.

For Bob's back knees, the folds were looking too large and wobbly because the whole pants were one stiff stylized material to hold the shape. Again, we needed to weaken the bends in the back knee to force the cloth to have a sharp fold there. We applied springs targeting the cloth warp to the top and bottom of the pants. This went a bit too far and turned into a hard line crease, but by wedging parameters and easing off on the springs, we landed on something we liked.

The bottom example shows a common problem where we introduce gaps in our clothes. This usually happens in the crotch and armpits. For loose clothes, it is more appealing to avoid gaps and turn these areas into straight lines, and avoid negative space there. This can be done in Tailoring or as a fix in Shot Sim.

Stylized Cloth

Overall, stylized cloth is still an ongoing area of exploration and improvement. The idea is to have mostly flat planes, but a few folds and breaks where you would draw them. We have gotten some nice looks on past shows, but it takes a lot of work and time. It relies on complex rigging, sim setup, and often Shot Sim cleanup, and we can't do it on every character.

Stylized vs. Natural Cloth

Incredibles 2 was somewhere in between *Inside Out* and *Coco*, in terms of realism. While the characters had graphic stylized shapes, the world was photo-realistically rendered and shaded. There is a concept of "truth to material", that things should behave like what they are. Cloth needs to match the level of caricature of the show. We needed to strike a balance between these two.

With Helen's pajamas, we were experimenting with graphic and stylized cloth. We played with unusual cloth parameters, that were stiff and formed sharp folds, and forced specific folds in knees and crotch. We could achieve the graphic triangle fold shapes you see in drawings, but it felt unnatural in movement. Helen's pants here should be silky, but they behaved pretty rigidly. We ended up softening the folds on I2 after seeing how this looked with the natural shading.

However, we were still able to achieve stylized but natural cloth on I2, using a more efficient method that ensures a good fit. We will talk about that in the next section.

Improving Out-of-Box Performance

Out-of-Box Overview

- A large part of Tailoring involves setting garments up for stable simulation, and trying to make them look as good as possible out-of-box in shots.

- We don't want to spend a lot of time cleaning up every shot, so it's better that garments can hit appealing shapes with most animation.

- That way, shot simulation time can be spent on interesting problems like art-directed movement and interaction.

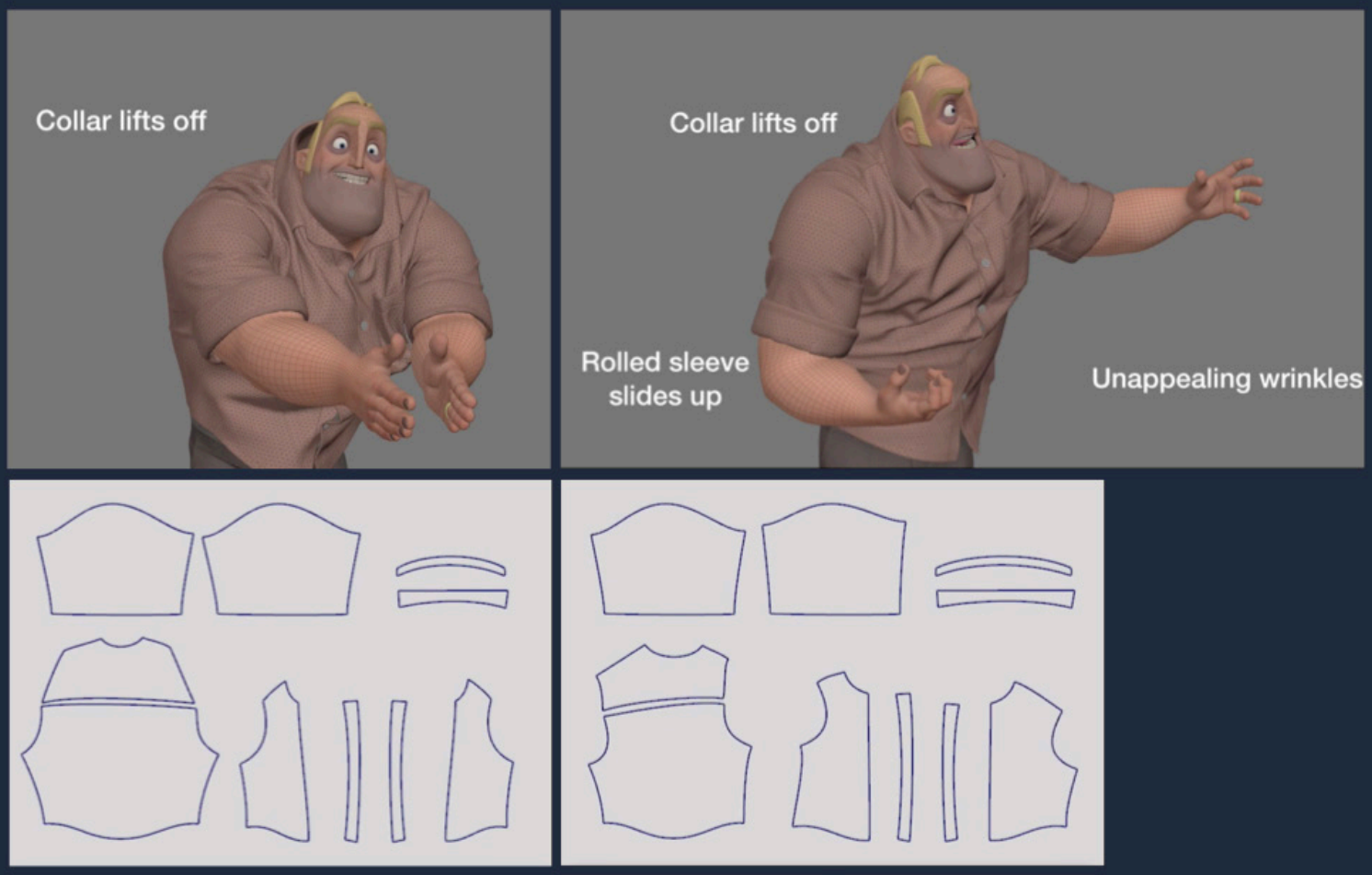
- Our most powerful tools for doing this are:
  - Cloth rigging and dynamic alterations to maintain fit in the shot
  - Hidden cloth for improving quality of folds and hitting silhouettes
  - Preventing snagging with the collision body to ensure stable sims

Dynamic Alterations

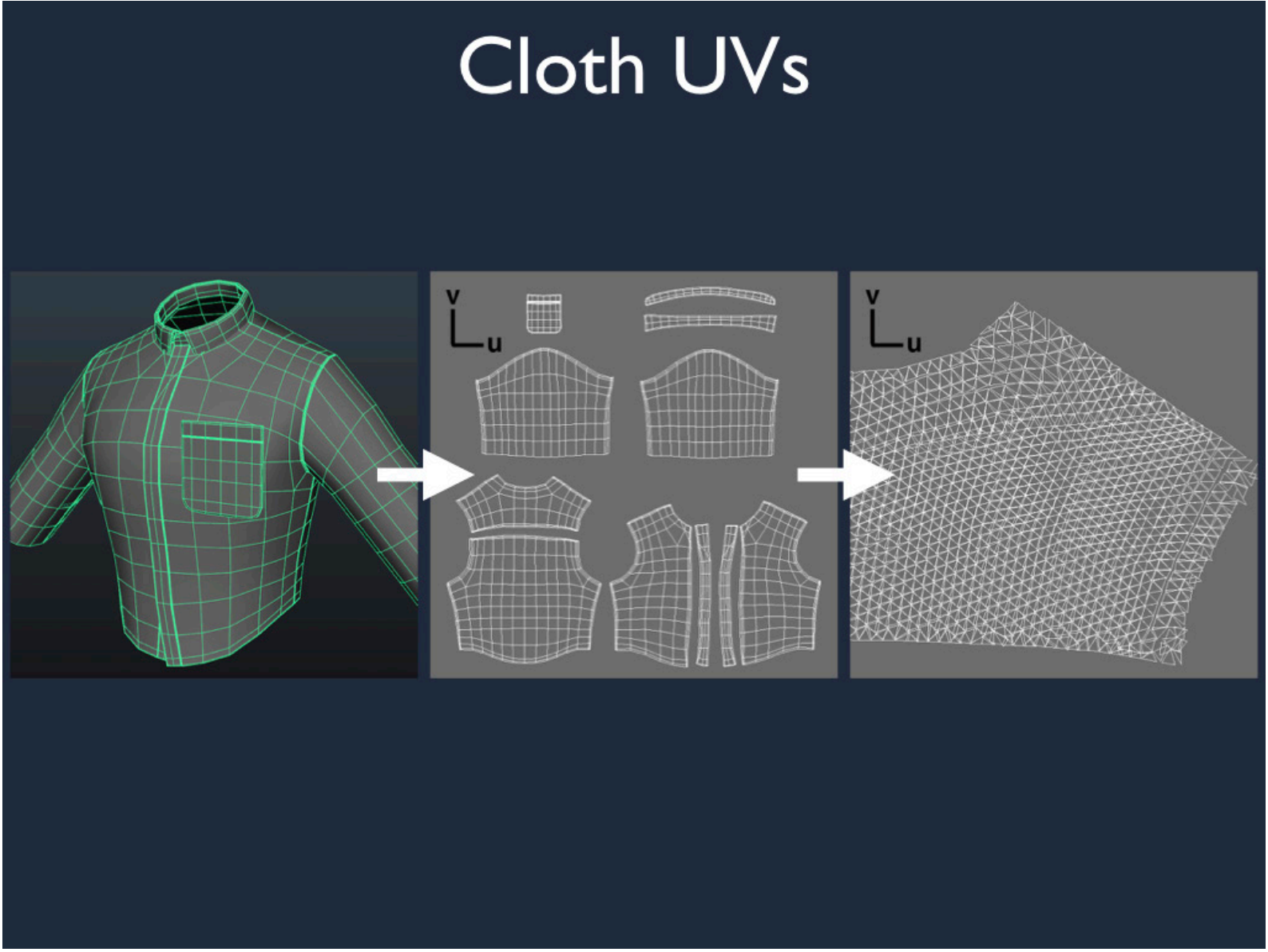
In computer animation, we often have exaggerated characters with cartoon volume changes and animation. In *Incredibles 2*, they were dressed in supersuits and tailored mid-century fashion. We also had stylized designs, but natural-looking cloth. How can physically-based cloth simulation hit these requirements?

Answer: Fit is Key!

Dynamic Alterations

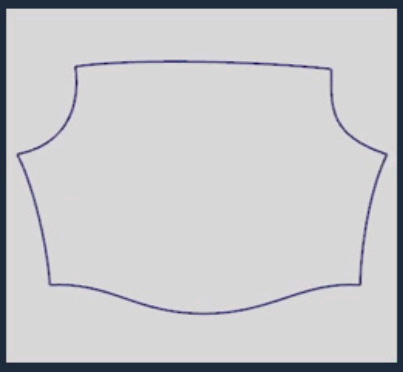


This is an out-of-box shot with Bob's shirt. The natural folds and detail are nice, but the shirt doesn't fit well throughout the shot. We need a way to dynamically alter a garment's fit in any pose while preserving important design elements, such as collar width, placket width, seam lines, print patterns, logo graphics, etc.

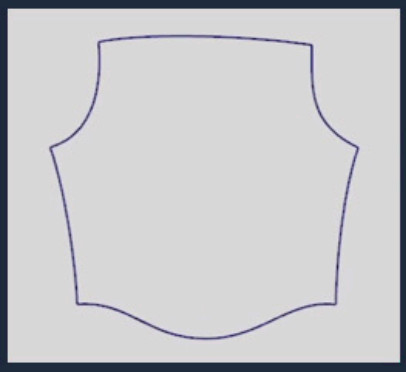


Fizt requires all cloth triangles have **UV** coordinates to calculate shear and stretch forces, by comparing the current shape to the rest shape in the UV plane. To lay out UVs, we often cut along the panel edges and lay them out roughly with vertical aligned in the V direction and horizontal in the U direction. UV layout is transferred to the Sim Mesh triangles, capturing their size and setting their 2D orientation. When UVs are oriented in a predictable way, they can be used for another purpose:

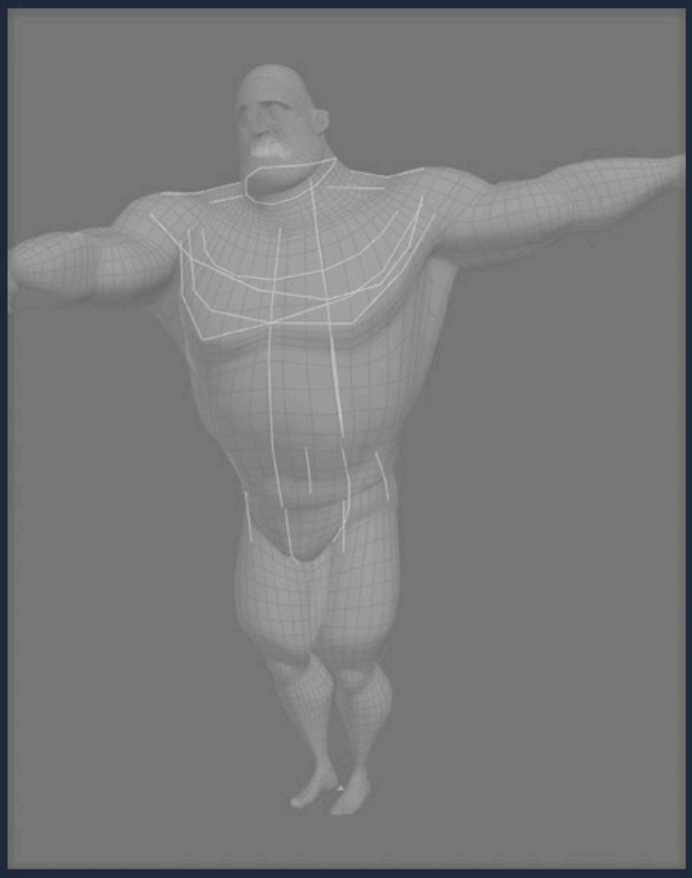
2D UV Alterations



Scaling in U



Scaling in V



Curves measuring body lengths

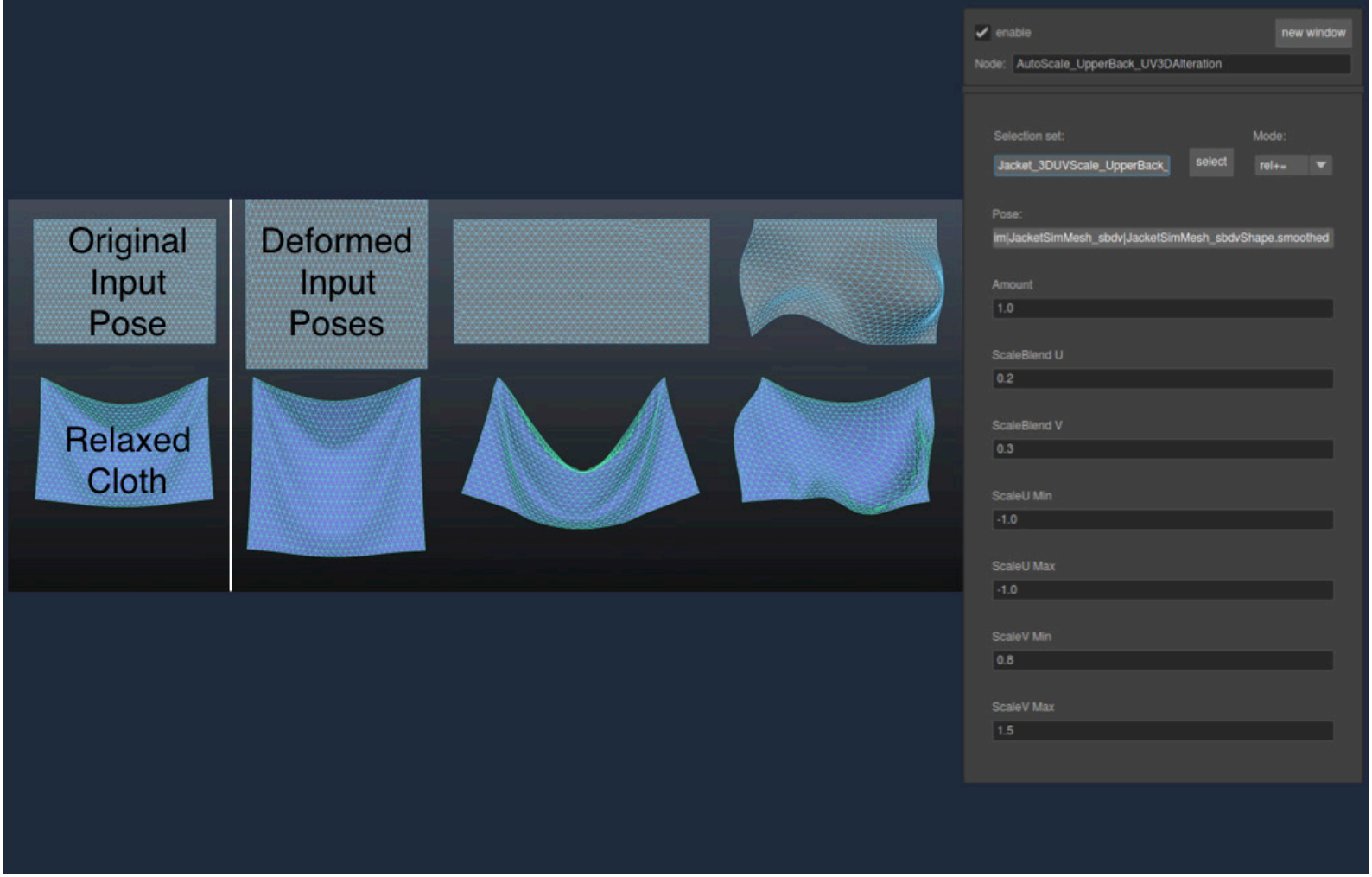
2D UV Alterations are a Fizt node that scales triangles in the U and/or V directions during simulation. We can use curves to measure the current length of body parts, such as chest/back width, torso/back length, and more, throughout the shot. The amount of scaling is based on the ratio of the current length to the original length of the body part. However, this is difficult to use for complex regions like the neck and upper arms, because there is more setup to break up and drive regions, and body length isn't always the measurement you need.

2D UV Alterations

Curve-driven 2D auto-scaling on back of robe

Here's an example of dynamic 2D UV Alterations being applied on the back of Bob's robe. There are two curves measuring length and width. The white region is the area that can be scaled up and down or side to side. If you don't scale the robe, the back is too tight, the collar gets wobbly, and the arms ride up. If you do, the fit is much more natural and relaxed. The plaid pattern also scales uniformly. Here we are also using 3D UV Alterations on the upper arms in combination with 2D, which we'll cover next.

3D UV Alterations



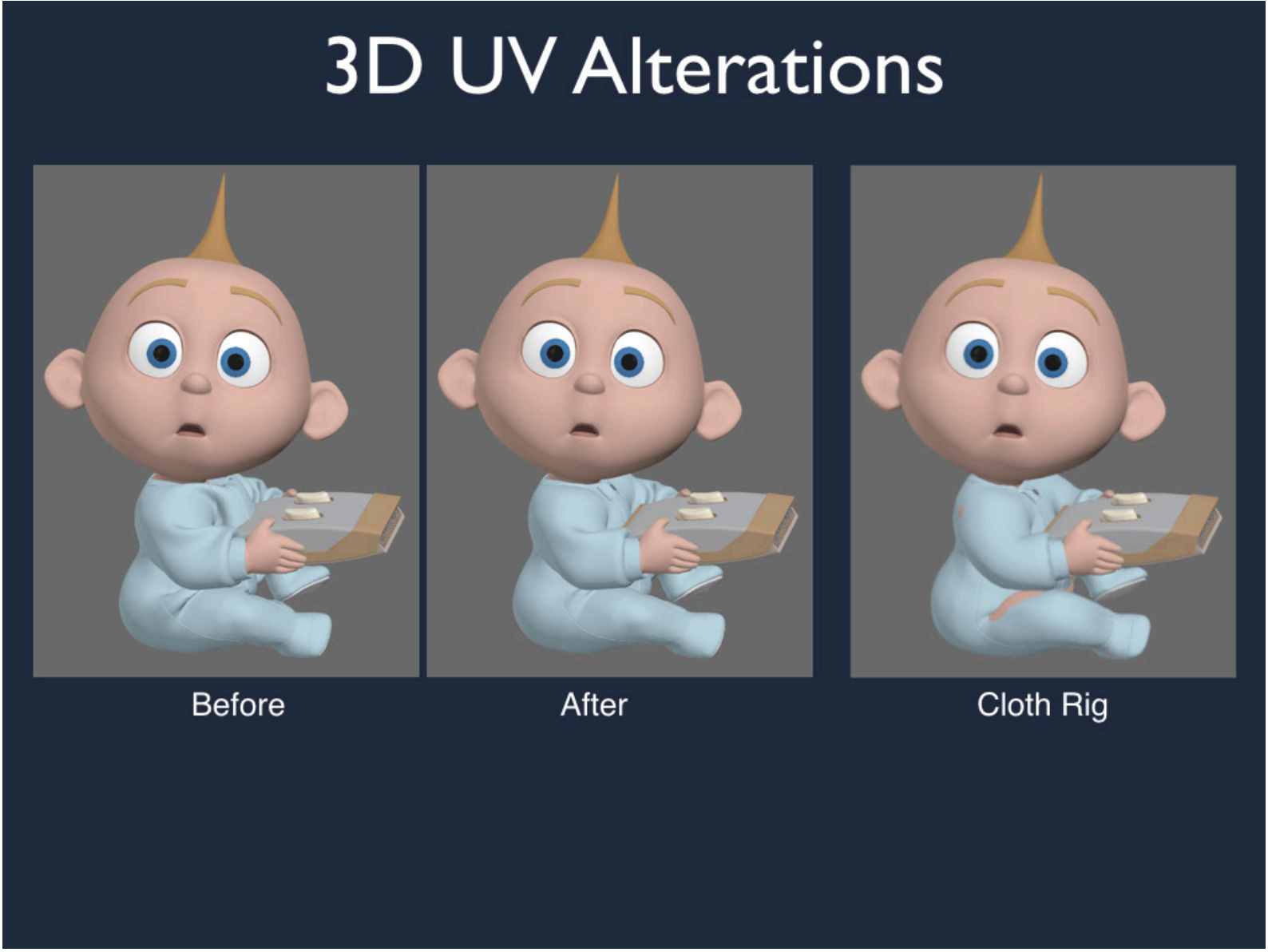
Recently developed by the Software Engineering team, **3D UV Alterations** are a Fizt node that takes a deformable input pose of your cloth mesh, and acts on a weighted region of the cloth. It changes the rest shape of every triangle to the input pose's shape during simulation, allowing 3D cloth deformation. Here we can see the original cloth mesh and the relaxed result. If we apply a new deformed input pose of the cloth (stretched in any way) - the result will match that in simulation. You can control and limit the scaling in U and/or V to preserve some 2D panel design elements.

3D UV Alterations

Using the Dynamic Alterations, we could break up our cloth into regions and control the shape of the panels by supplying the simulator a frame-varying rigged target pose, or a **Cloth Rig**. The default cloth-to-body warp has problems, so we used **Cage Meshes** modified with deformers (relax, delta mush, quasi-static cloth, etc.) for fast and usable cloth rigs.

The cloth rig doesn't need to be perfect in this case, because we can take advantage of U and V controls on the 3D UV Alteration nodes. We apply 3D autoscaling on the upper half of the shirt, and scale only in V for the placket, and mostly in U for the front of the collar.

You can see the end result in simulation fits much better throughout the shot.



Jack-Jack's onesie is an example of when we want a very good cloth rig, since the whole garment must fit well, not just the upper body. We have multiple Alteration regions on different parts of the onesie. Here you can see the extra material getting eaten up in the "After" sim, but not enough to look fully rigged. The rounded shapes and slight folds are a very appealing part of this design.

Performance Improvement

Out of box sims before and after 3D Alterations + Kinsprings

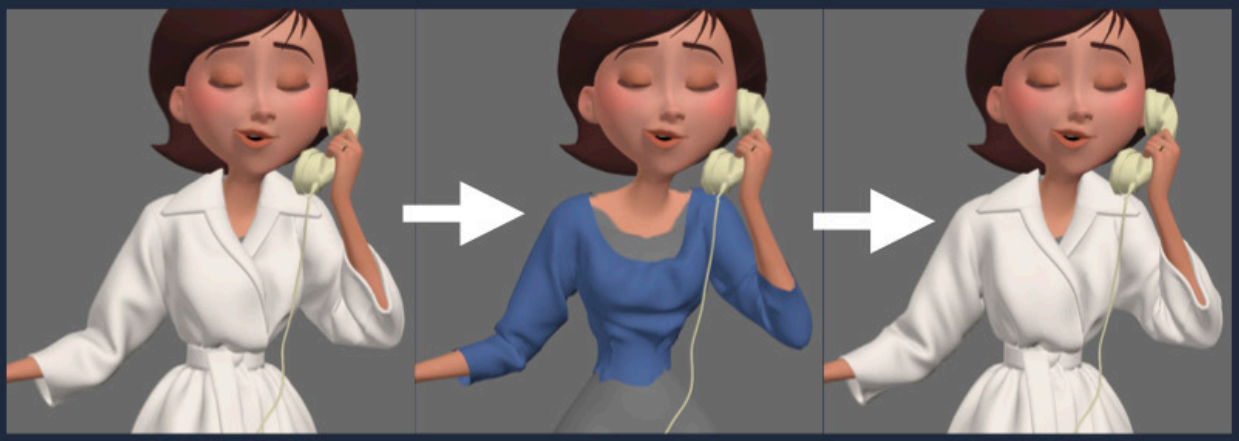
Here's another out-of-box example of Deavor, who didn't stretch as much as Bob, but needed a consistently perfect suit fit with a tight but relaxed drape. We used this technique on the supersuits, and many of the civilian garments to improve out-of-box performance, saving time in shot simulation.

On all of these examples, we also use strong **Kinsprings** (springs that target the pre-sim cloth rig, or the Kinematic Points), on regions like the back and inner collars. Kinsprings are very powerful tools, but they rely on a good cloth rig as well. Kinsprings took the place of typical back-collar Glues and performed much better, because the collar wasn't affected by neck rotation.

We found that maintaining a good fit was the key to stylized-but-natural cloth. After all, designers in the real world can make "stylized" couture garments, and they look that way because the fit is perfect. We will continue refining our dynamic alteration and cloth rigging techniques in future shows.

Hidden Cloth

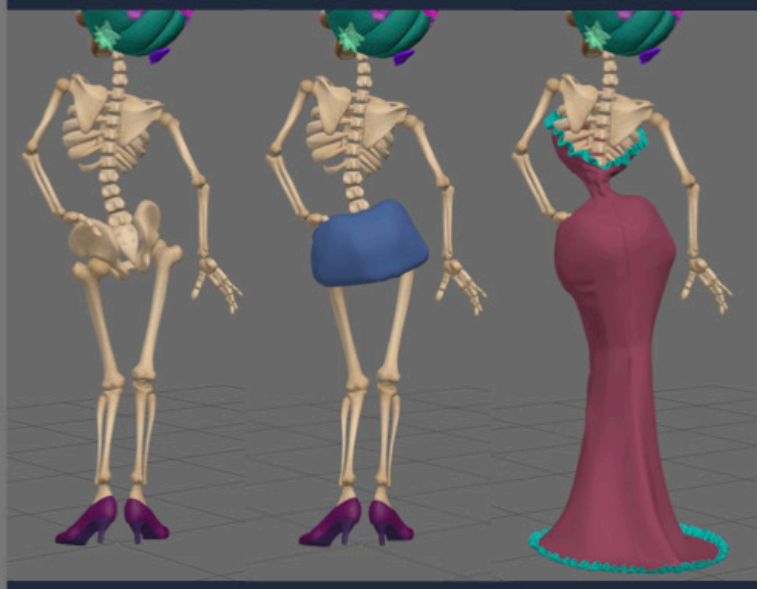
Use hidden cloth meshes to fill and pad garments, producing nicer folds and structure



One useful way to improve the look of garments is with hidden cloth. Real clothing often has an extra lining layer, shoulder pads, etc. It is also draping over soft skin and more realistic proportions. These physical details affect the look and drape of the cloth. If we want to mimic that naturally, we should try to add this extra padding in. Look at the difference in Helen's robe sleeves. The folds don't collapse nearly as much after adding the hidden shirt, instead it looks nice, rounded, and plush.

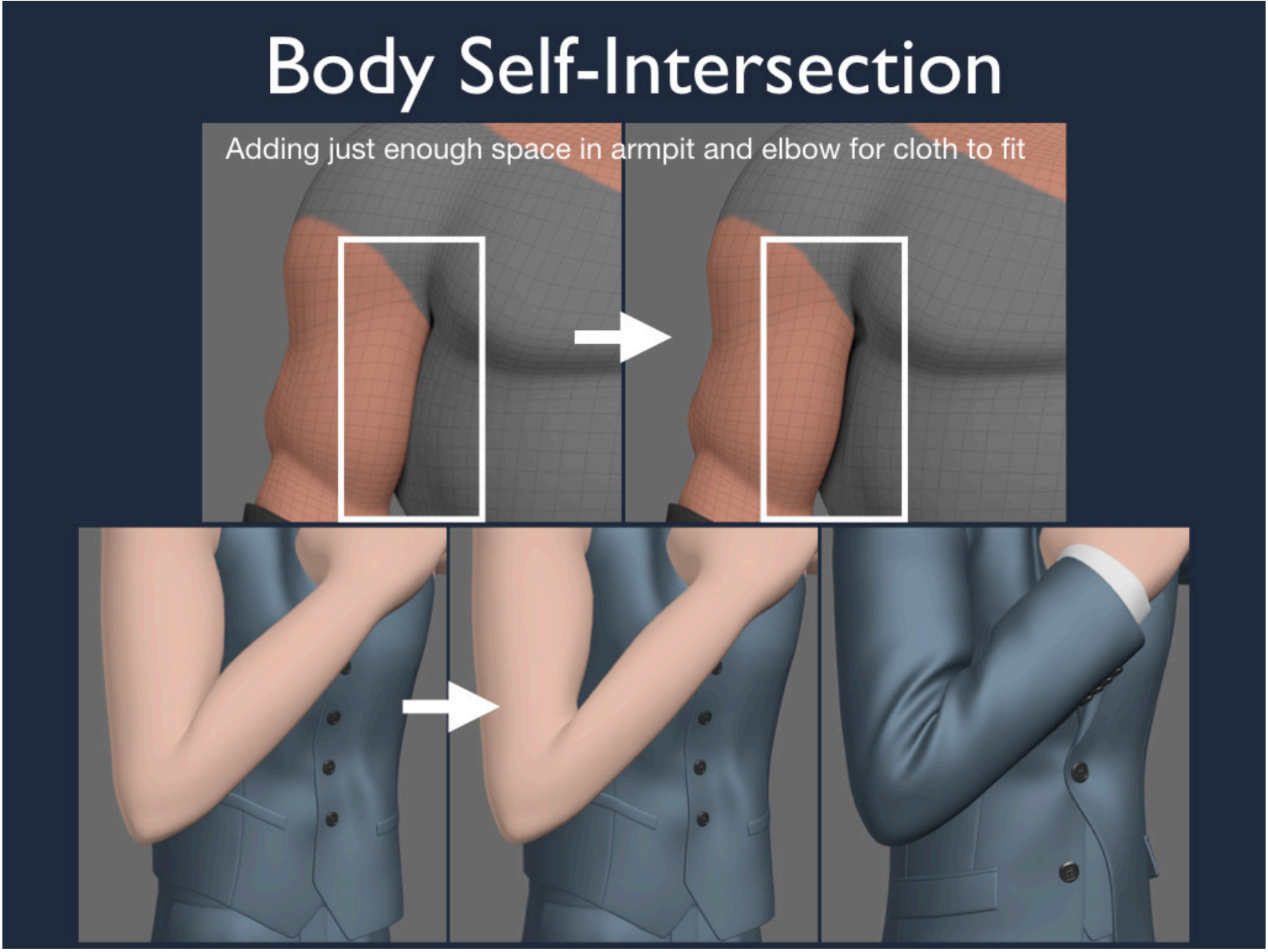
Hidden Cloth

Pillow in pelvic bone to prevent dress and apron from collapsing down



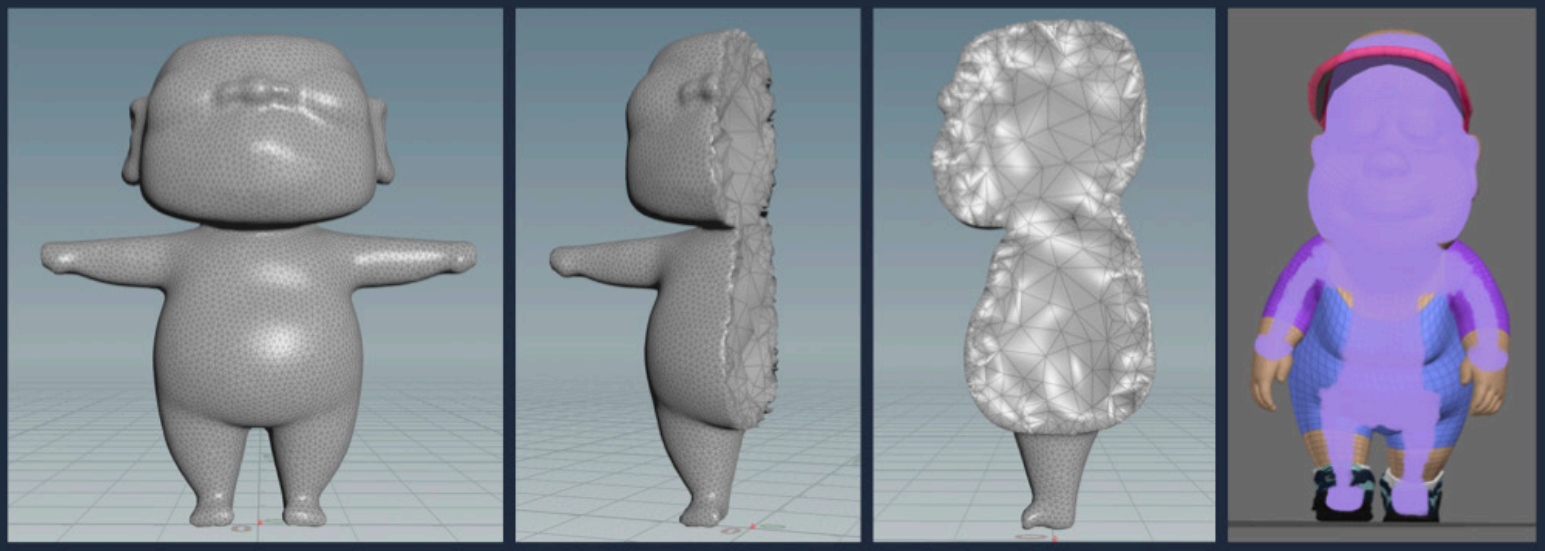
Padding over bones to create rounder shape

Sometimes we have situations where we want skeletons to wear clothes and look more filled out. We can add pillows and extra padding to help here. These kinds of solutions are often necessary for stylized characters whose bodies can not produce the art-directed silhouette by themselves.



One large problem we need to solve to make cloth out-of-box is to prevent snagging due to body self-intersection. If there is multilayered cloth, extra clearance space must be made in these areas. This regularly occurs in the armpits, elbows, knees, and crotch, and we must pay attention to it when tailoring. Some of our standard solutions are using **Kinematic Colliders** in the armpits and rigging gaps in the elbows when the arm is sufficiently bent. These work most of the time, but kincolliders can have popping artifacts and will not work well with complex collisions, and rigging elbow gaps doesn't always hold up with extreme poses. It is difficult for these techniques to be used on other common problem areas too, like the crotch.

Body Volume Sim



On Bao, body self intersection was a huge problem, because of the chubby character proportions. We did not have the time to manually rig or sculpt all of these out by hand. So we developed a new more robust technique to clean up body self-intersections - **body volume sim**.

First we generate a **tetrahedral mesh** using Houdini and warp it to the body.
We hard constrain the head, hands, and inner tetrahedron core. We can simulate this volume using Fizt, with standard FEM to generate forces.

https://graphics.pixar.com/library/CleanClothInputs/paper.pdf

Body Volume Sim

Using body sim, space is created in areas that rigging could not achieve.

We can get gaps for the cloth to rest in complex areas, such as head to neck, elbows, armpits, crotch, stomach to legs, etc. By doing this, the cloth is much more stable, and there are fewer snags.

Additional Collision Setups

To improve the stability of the collision body in cases where body sim won't work, such as rigid skeletons or mechanical wings, we might need extra help. On Hector, we fused his joints with cloth, so that the pants and sleeves wouldn't get caught in between bones. On Imelda, whose animation was not as extreme, we used **radial force fields** on her joints, pushing her skirt away from the area to prevent snags. We did the same on Screech's rotating wing base underneath his cape.

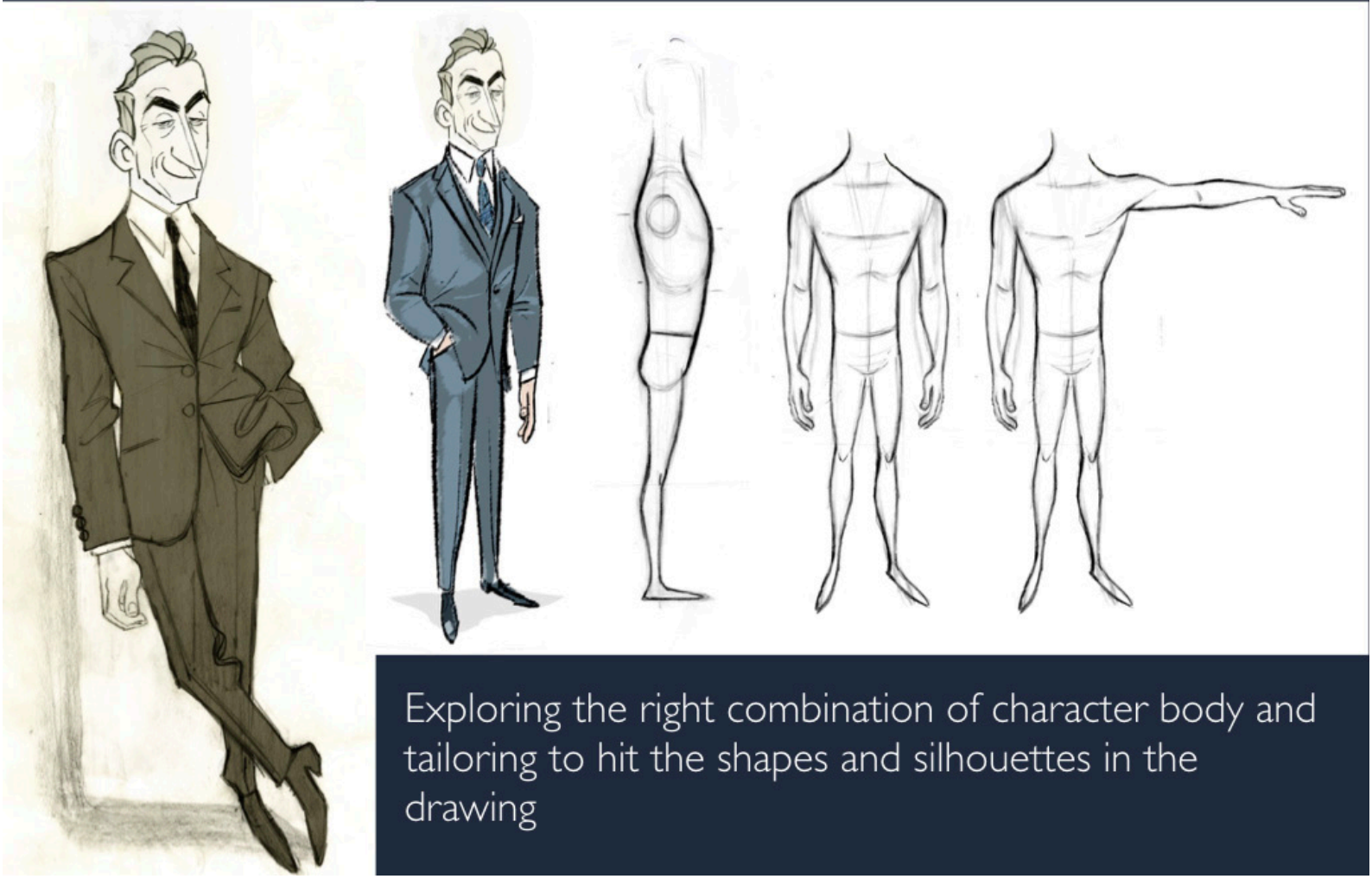
As a heavy hammer, we can always tell cloth regions to ignore collisions with collision body regions or other cloth regions. This is called **Collision Invising**. We might activate it between hands and pants, for example, because these two areas will unlikely need to interact, and it will prevent snags if the hands go through the legs in animation.

Cross-Departmental Collaboration

Collaboration Overview

- We covered the Tailoring side of building garments
- But the final look and performance of costumes relies on many different departments in the pipeline
- Close collaboration with the following departments is very important:
  - **Art**: Designs the costumes, as mentioned before, and sees them through Tailoring approvals, ensuring they hit the correct look
  - **Animation**: Provides test shots and motion/silhouette notes during Tailoring, works with Shot Sim for cloth interaction and performance
  - **Shading**: Shades the garments, giving context for Tailoring and Sim Setup, and helps increase variety in re-used garments
  - **Lighting**: Lights the shots, giving context for Shot Sim
  - **Crowds**: Works with Tailoring and Shot Sim to ensure costumes are diverse and stable enough in the crowds
  - **Software Engineering**: Helps improve our tools and workflows

Translating Drawings to 3D Form

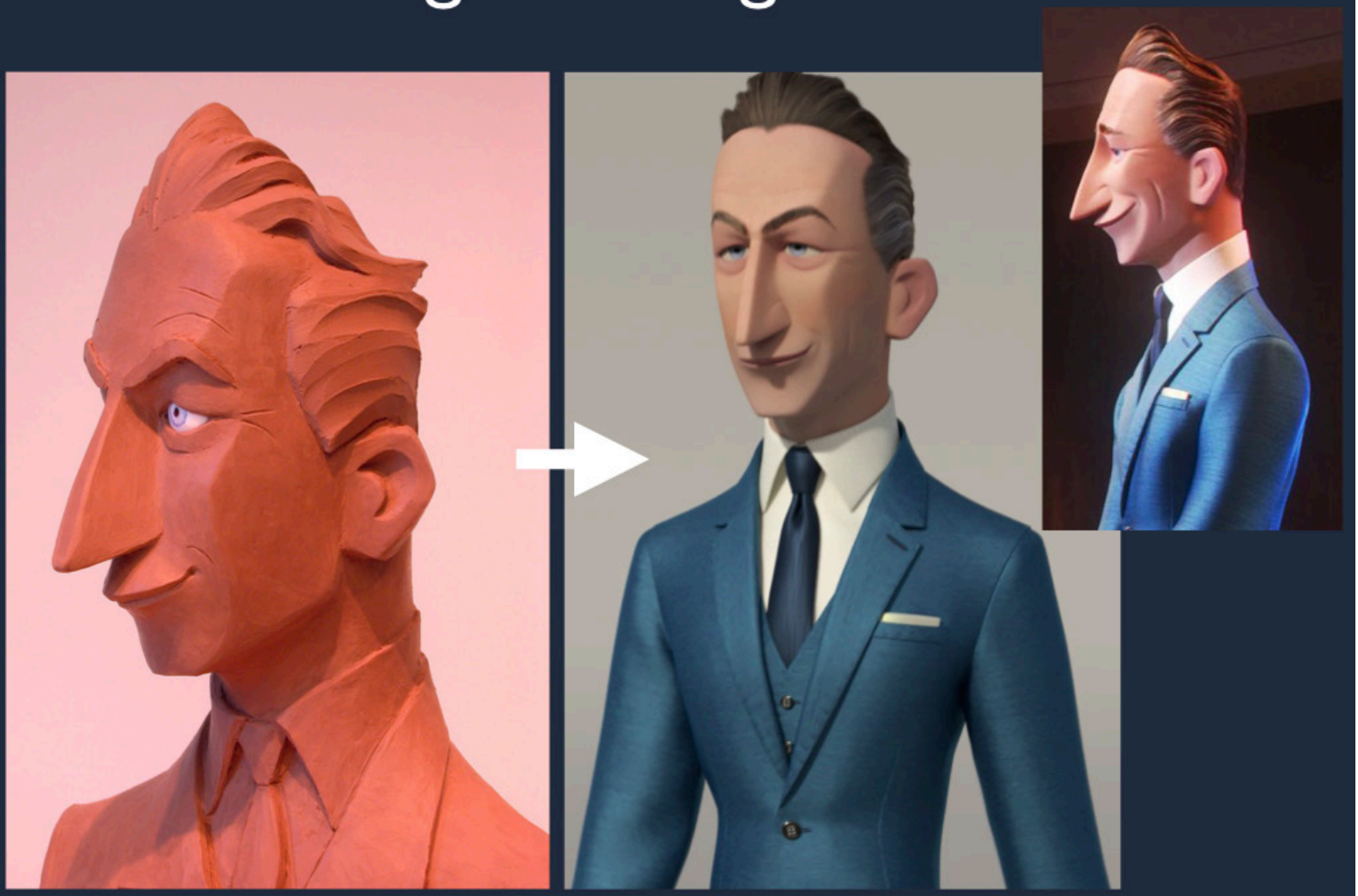


Exploring the right combination of character body and tailoring to hit the shapes and silhouettes in the drawing

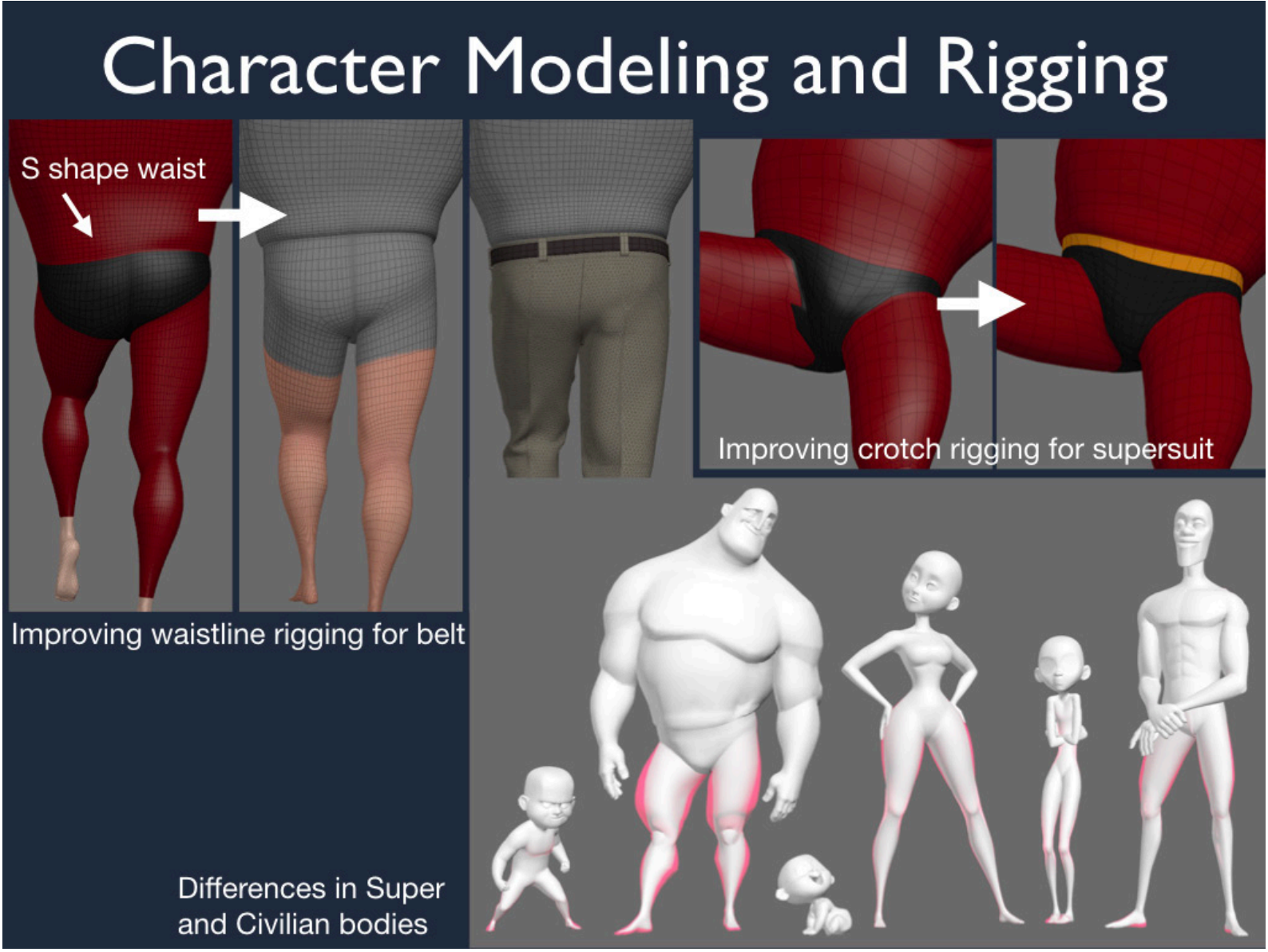
It is important to work closely with Character Modeling and Rigging because the body and clothes have to work together to hit the shapes we want. We need to analyze the drawing and pick out the elements that are important to hit. On Deavor, it's the strong shoulders that slope into a wide neck, a skinny waist that causes the jacket to taper in quickly with a tension fold, the bottom of the jacket flaring outward, and skinny pants that taper into points.

We try to design the body underneath the clothes. In this case, we realize that the waist and hips might be a bit too skinny to hit the jacket flare. Skinny knee joints look good by themselves, but they cause pants to fold in strange ways, and it might be worth thickening them. The jacket arms look relatively thick, but under two layers of cloth, the arm itself might not have to be that wide. We want to give room for folds to happen in the shoulders. This is a constant back-and-forth between Tailoring and Modeling.

Translating Drawings to 3D Form



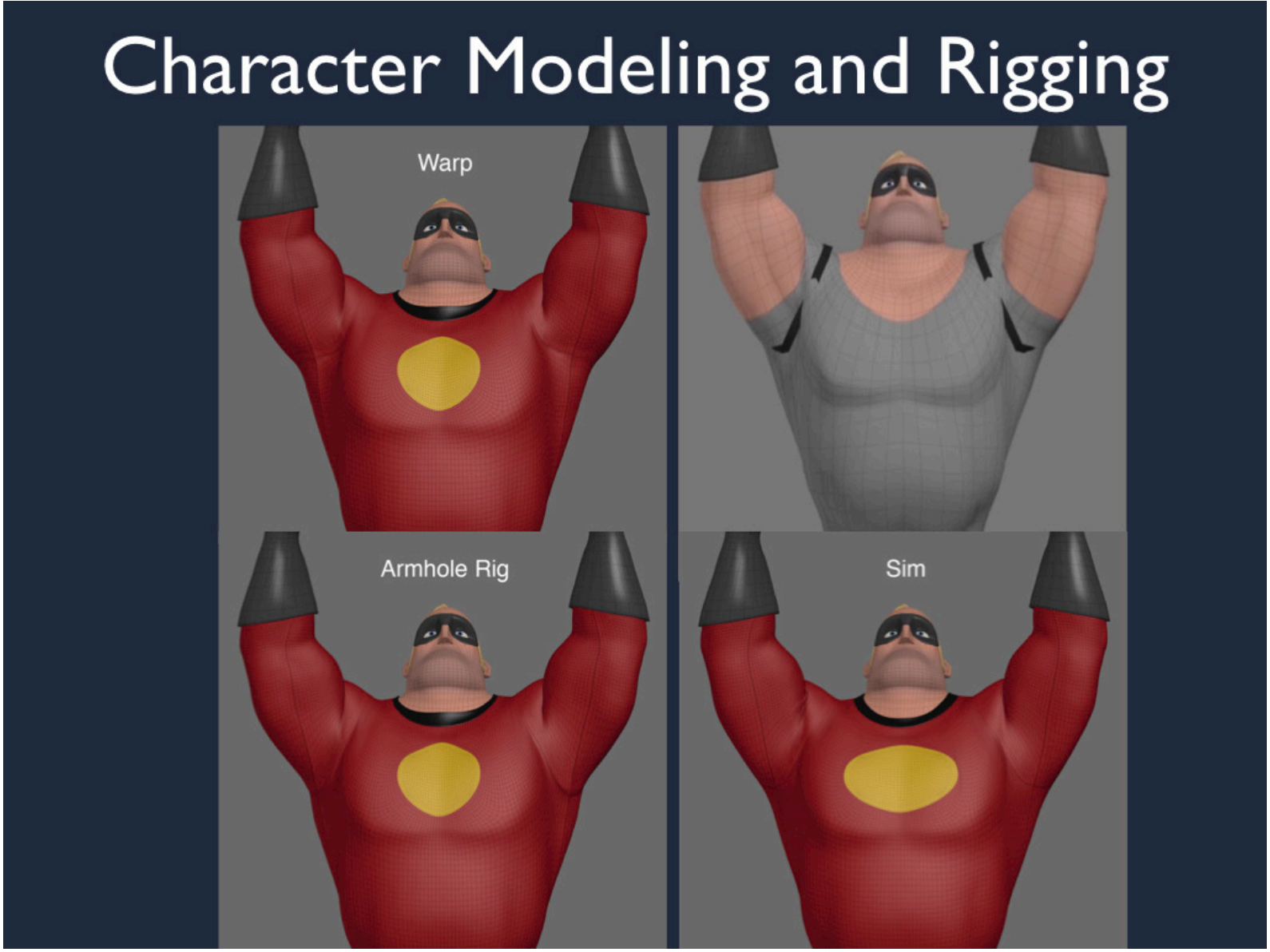
We often create physical clay sculptures to explore shapes in Art. When we translate this to CG, we are trying to hit elements like the tight collar, pointy collar tips, skinny tie, and sloping shoulders. However, we decided to round the shoulders out more than the sculpt.



We also need to work with Character Rigging.

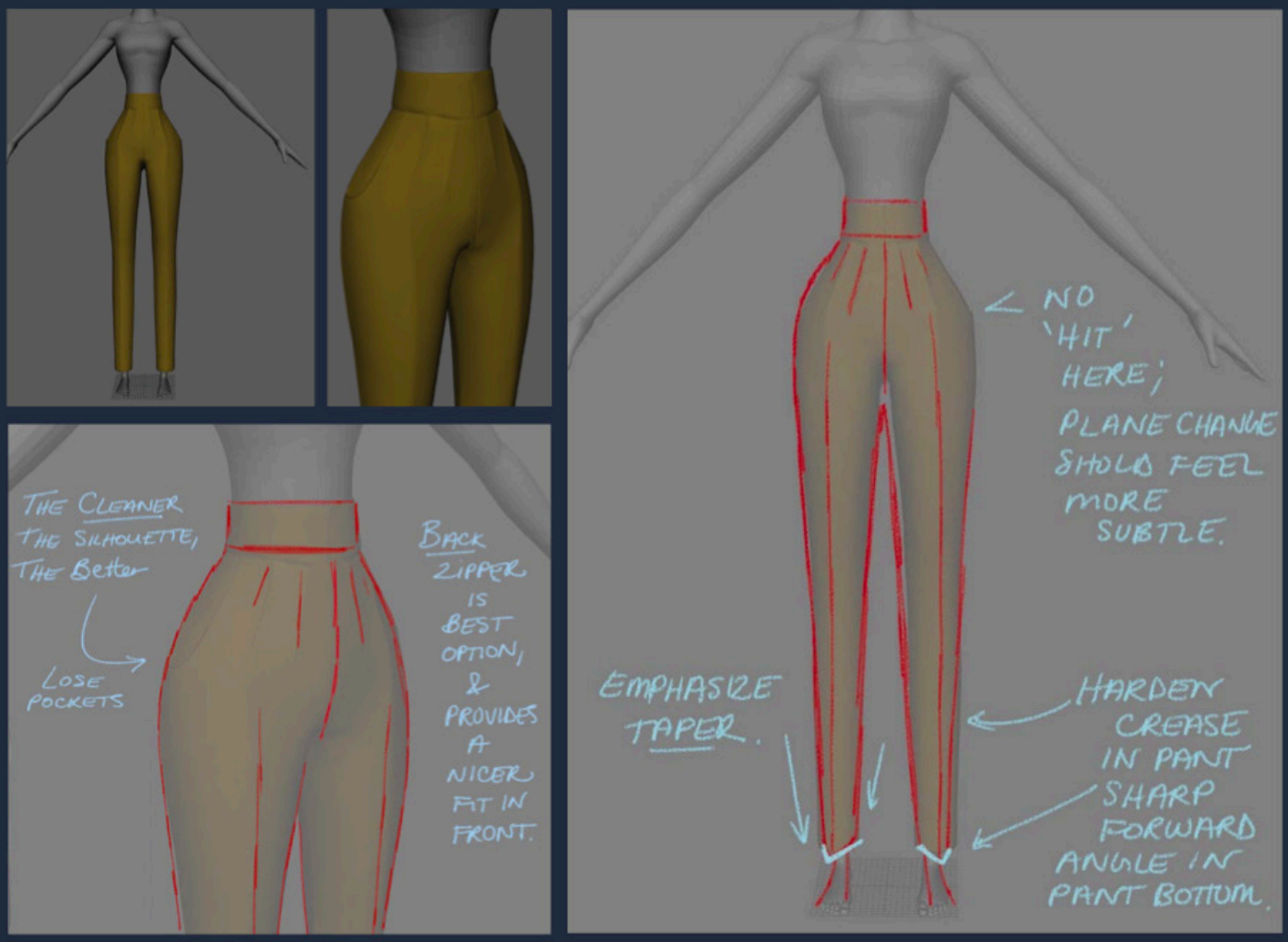
Because we constrain cloth to certain key points on the body, these areas need to be rigged well, even if they're covered by cloth. One example is the belt line. We don't want an S-shaped waistline when a character walks and runs, because you will see that unnatural curve in the belt. On Bob we tried hard to rig it as straight as possible, while still being able to in the counter-rotation between his torso and hips. We also need good body deformation in other areas like armpits, crotch, and elbows. Ideally a character won't gain and lose too much volume in typical poses.

For the Incredibles family, we wanted to use the same model for the Super and Civilian variants. The Civilian garments had to look a lot more streamlined and less bulky, particularly in the legs, so Rigging built controls to slim down the legs and widen the knees.



It can be helpful to have extra **rigged controls and guides**, such as arm hole and leg hole guides for Supersuits. This gives us something else to warp cloth to, improving our cloth rigs (which is useful for 3D alterations and Kinsprings). These are areas that need to slide over the body topology, or have a slightly different setup than the normal rig, and they help our garments immensely.

Art

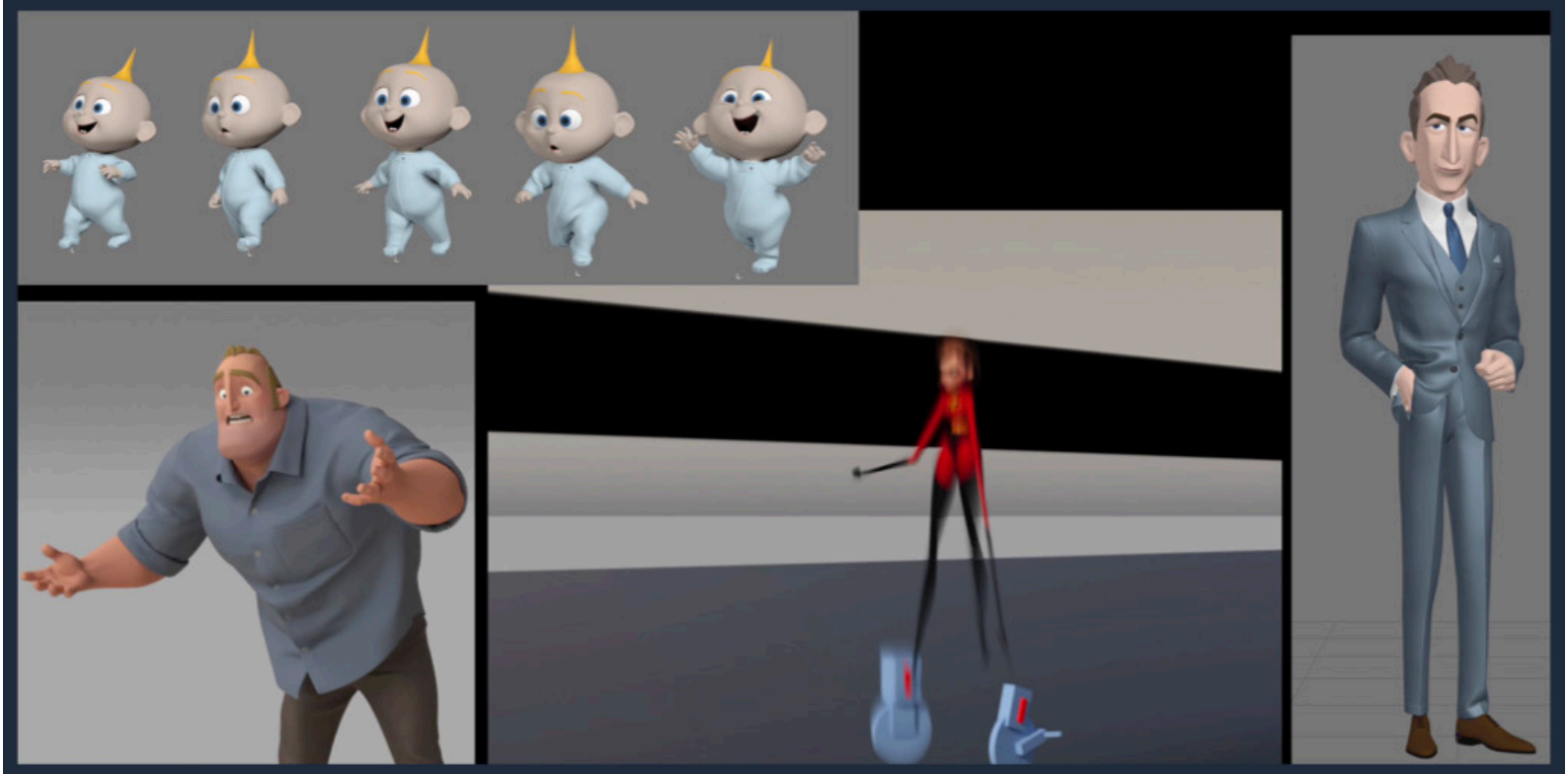


In addition to designing the clothes, Art works with Tailoring to give design notes for construction. Art thinks about silhouette, proportion, thickness, appealing shapes, stylized vs. natural looks, and garment details. They help guide the garments through director approval. Occasionally, tailors will design parts of costumes themselves too! We all work together.

Art

Here is a drawover from Art, showing the original tailoring, and ideas we can use to give it a nicer drape. In dresses, draping looks better if it's more gradual, with lines continuing from the waist to the bottom of the dress. We don't want competing lines in different directions (unless it is very intentional in the design).

Animation



Test animation for Tailoring

In the “Shot Simulation” section, we will talk about collaborating with Animation for cloth interaction, movement, shape, and line of action in shots. Animation is also involved in the Tailoring stage. During this time, they provide test shots so we can figure out how the cloth should fit and move. Where do we want folds, how do the shapes affect the read of the character and the silhouette? Will we need to build in controls to the garments so animators can pose and interact with them? This is where we answer important performance questions before the costumes go into shots.

The Shading team can shade in-progress tailoring inventory to help us get approvals on tricky materials, including several supersuits and Helen's robe. It is helpful to have accurate shading and lighting response to get a sense of how well the movement properties are working. Fuzz, patterns, and shininess can all drastically affect the look of garments. Hardware shading is helpful to see where extreme pattern stretching is happening, such as Bob's bicep.

Crowds

For Crowds, we try to create a diverse population of background characters using strategic clothing choices. We are continually trying to figure out ways to make crowds more efficiently and look better, but in ways that don't draw your eye. We mix and match clothing, refit and reuse to different body types, and use shading variants heavily.

We always question what would make BG human construction more efficient without compromising quality. How do we balance number of body types vs. visibility of repeating shapes? Do we want our BGs to look quirky or more generic? Does refitting cloth have real gains or should we tailor garments from scratch for different bodies? On every show, we try out different ideas.

Crowds

BG cloth sims running automatically on mocap data

It is very important that crowds characters have stable cloth when simmed, especially in an action movie where they will be running around. In tailoring, we typically only test on a walk cycle and pose for reviewing BGs. But on *Incredibles 2*, we could automatically run sims on mocap and animation library shots to test stability, and we found a lot of problems.

Tailors took our BGs through a stability pass, so they could hold up in runs and seated shots without instability. We also worked to improve our cloth rigs, so you did not have to sim the crowds in far away shots.

However, we did not anticipate how many close up still shots we'd have of the crowds. These can be the hardest shots and our BGs were not always built for them. This is something to consider as well. We will continue to explore BG strategies in future shows.

Costumes in Shot Simulation

Shot Sim Overview

- Ideally, after the pre-sim improvements made in Tailoring and Simulation Setup, the garments should behave well out-of-box. The costumes should fit and have reasonable movement, and the bodies should not cause snagging

- However, it is hard to predict what the animation will be in shots, and we often run into unexpected challenges

- Shot Sim consists of three basic responsibilities:
  - **Shot-specific setup**: Adding external forces, collision setups, and cloth interaction, occasionally collaborating with Animation
  - **The nitty-gritty**: Cleaning up body self-intersections, snags, oozing and jittering, poke-throughs, fixing problems we missed in Tailoring, etc.
  - **Adding artistry**: Plussing the shot with art-directed movement and sculpting to hit shapes, adding to the performance and feel

Setting Up Colliders

Our cloth sometimes collides with complex geometry. In most cases, we can approximate this geometry with simple shapes, such as cube, sphere, and capsule **colliders**. This is often more stable than using the actual geometry, especially for hands, which often cause cloth to snag due to self intersections.

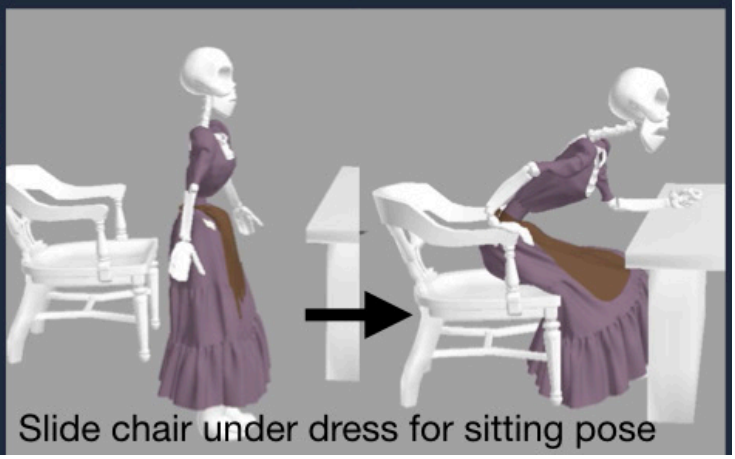
Sometimes it's easier to use the actual geometry because it is a strange shape or animated heavily. This is the case with Evelyn's bags. Here we need to make sure to clean up any intersections caused by the bag colliders. We also try to turn the bag meshes into a single mesh for the collider. In this shot, the cloth still snagged on the bags, so we added extra radial force fields to push it away from the problem areas. We also used radial fields to keep cloth away from Evelyn's face.

Preroll and Start Pose

Standard arms-down preroll

Complex start pose created with interactive simulator

Use cage mesh cloth rig to put suit in hands

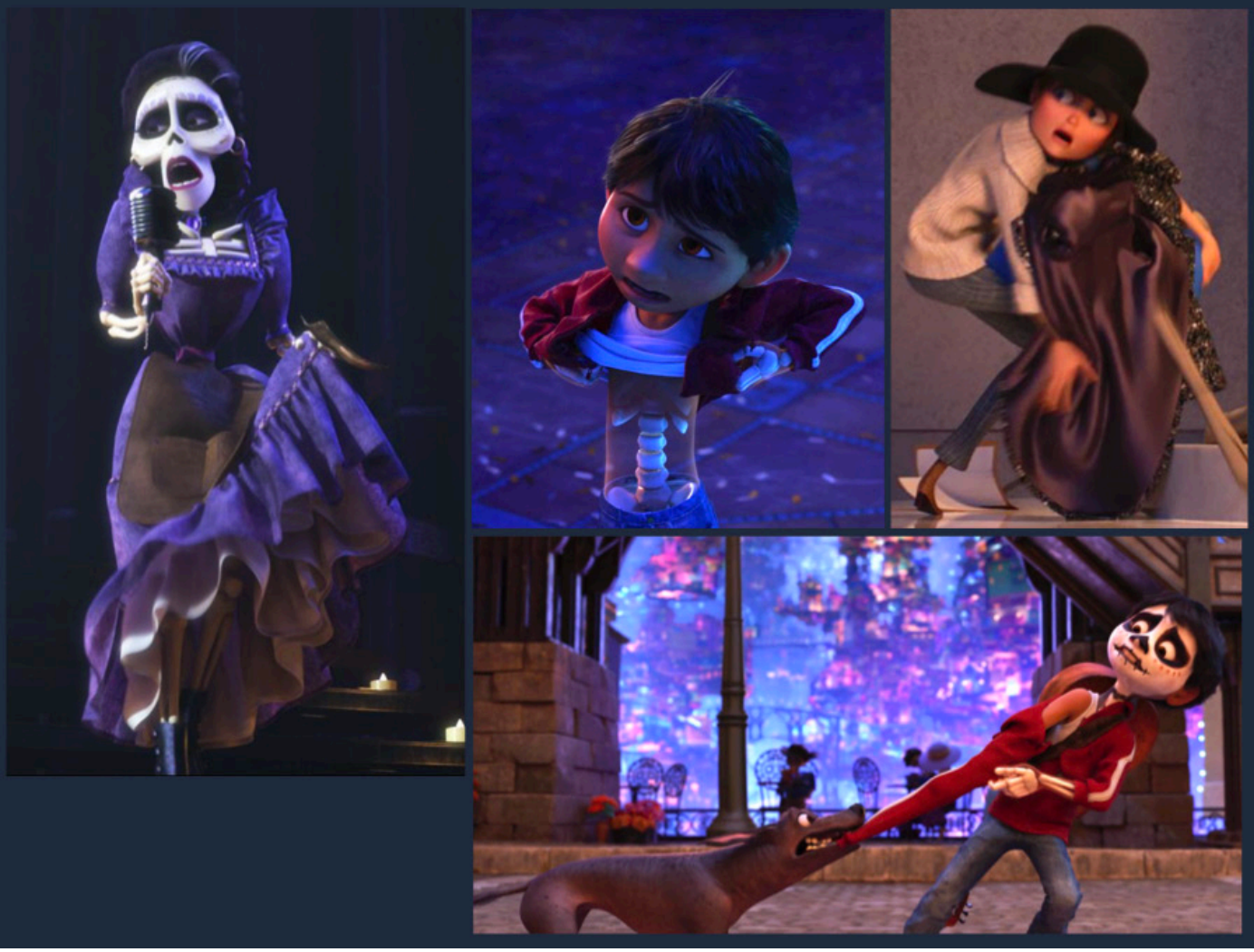


Slide chair under dress for sitting pose

We need a way to get the clothes into the right pose for the first frame of animation. We typically tailor our cloth to the body with the arms down 45 degrees. We use a **Preroll** to animate the body from the tailored pose to the start pose over 15 frames, with 10 extra frames for the cloth to settle at the end. We can also animate colliders, such as chairs, bringing them in from a non-intersecting position so that they collide properly. This works for most shots.

Sometimes the start poses need to be more complex and art-directed. When Violet was trying to destroy her supersuit, we used a cloth rig to place the suit in her hands at the start, then let the simulator take it from there. Helen's robe needed to hit specific draping notes on the bed, so we used our **interactive simulator** to generate the start pose, pulling the cloth around until it had nice shapes, then simulated the shot.

Cloth Interaction



Cloth interaction is difficult, but it adds so much to the acting performance and immersion in the world. We are always working to make cloth interaction more intuitive for animators, so that they can animate with the clothing in mind. Many shots require a close back-and-forth collaboration between Shot Sim and Animation.

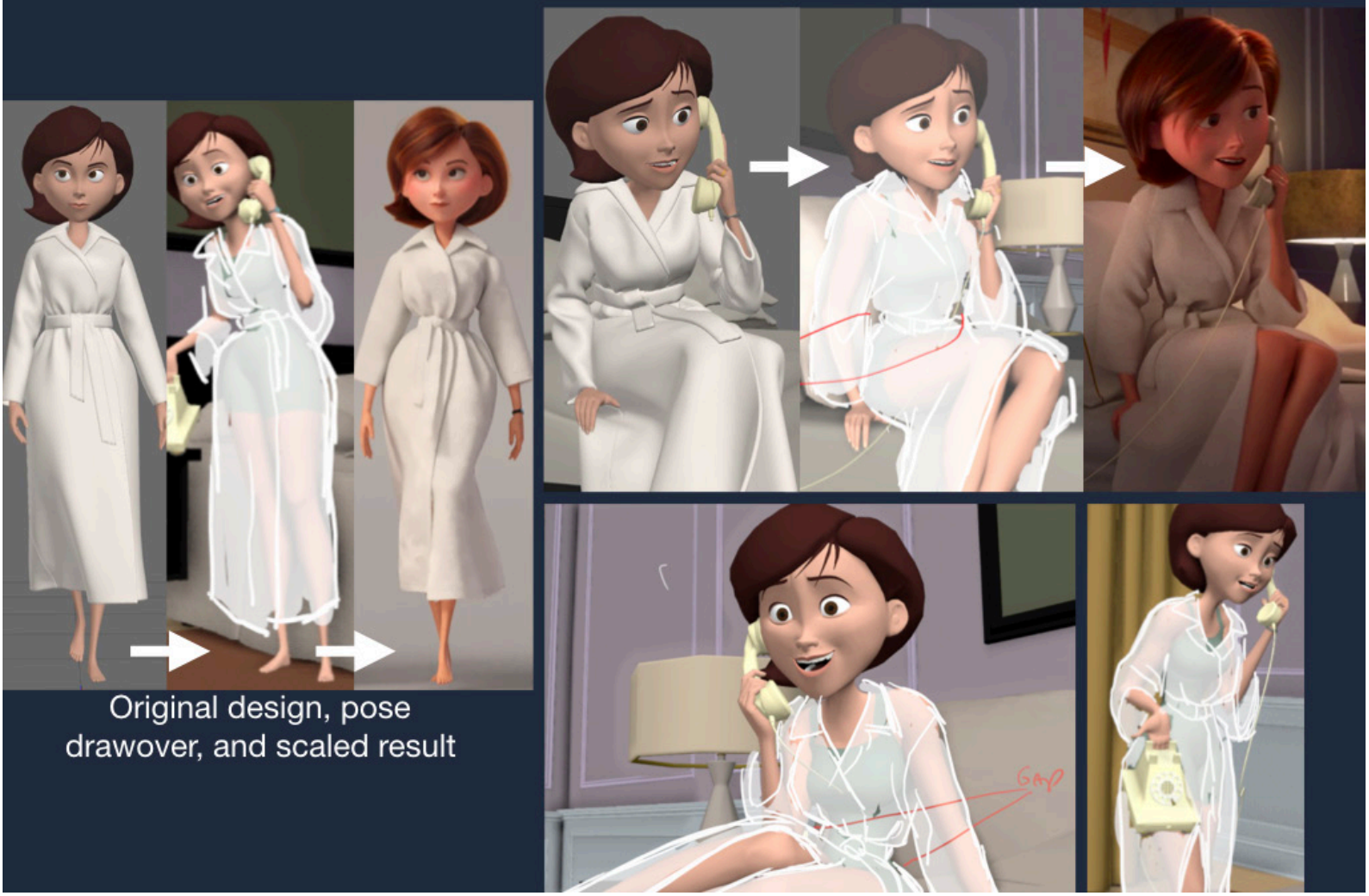
Cloth Interaction

Besides collisions, the most common way to interact with cloth is by grabbing it. We have a tool called **Sim Grabs**, which are spatial constraints that we can animate to drag the cloth around. When Evelyn takes off her coat, we use several Sim Grabs to make sure it matches the animator's choreography.

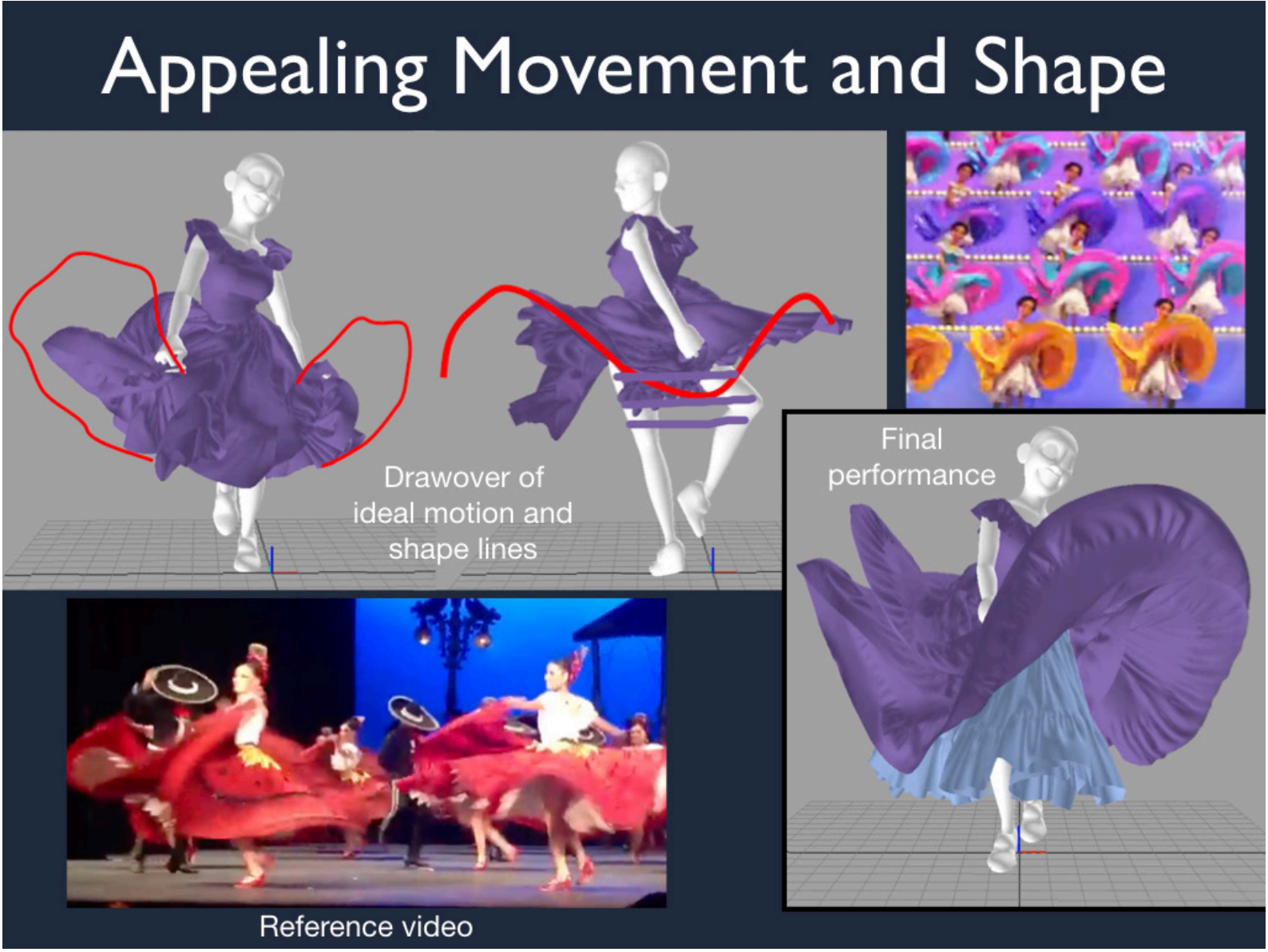
Cloth Interaction

For one-off shots like Evelyn's coat, a lot of back and forth is expected. But Miguel puts his hands in his pockets and acts with his hoodie throughout the film. For cases like these, we want to build a rig for animators to use. We use a combination of radial fields and Sim Grabs constrained to Miguel's hands, and controls that puff out the pockets. Animators had a nice set of controls and instructions on how to use them, so they often set up pocket interaction shots themselves. More and more animators are running cloth sims while they work, and this has been beneficial for acting, movement, and clean inventory.

Appealing Movement and Shape

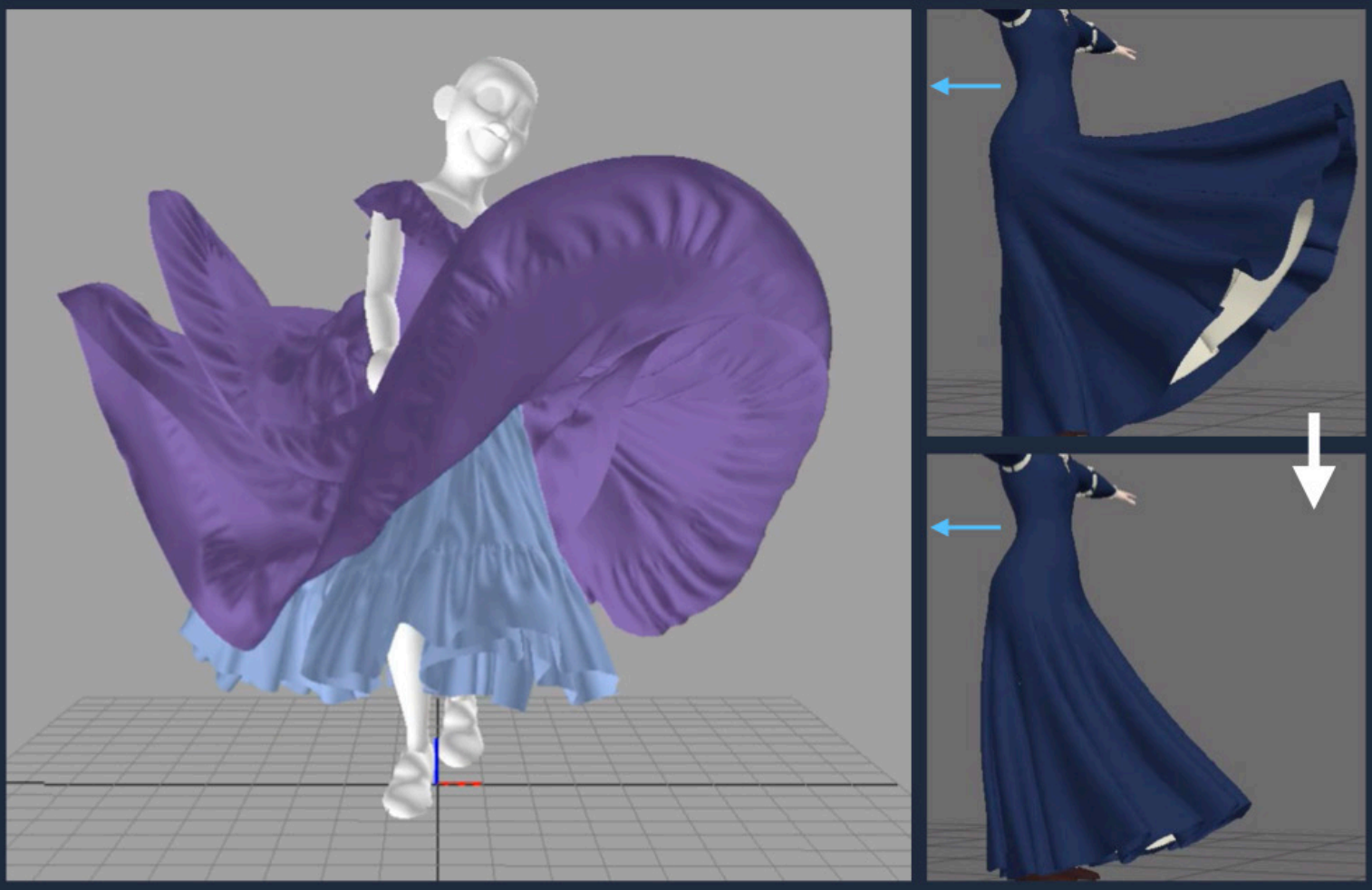


When tailoring Helen's robe, at first we tried to mask her curvy form with a more straight drape and wider waist. But after running it in an early test pose, Animation realized they wanted to to see the negative space gaps caused by a more cinched waist, looser bodice, and chunky belt. We took the original garment and scaled the waist band in, and widened the bodice and arms. The result looks a bit extreme in the walk cycle, but in the shots, it looks nice and natural. This is a good example of changing tailoring to work with specific shots.



On *Coco*, we tailored a first pass at the dress, but we wanted the dress to to hit certain large curves and shapes and move in a certain way. We also had to make sure the dress didn't swing up too high for modesty. This involved a lot of back and forth between Tailoring, Sim, and Animation. In tailoring, we lengthened the dress and added a petticoat. In animation, we added higher hand positions and broader motion. In sim, we added more drag and removed rotational acceleration on the fast motion.

IFG and Killing CTM



CG animation often is snappier and less physical than real motion, and cloth can fly around too much when trying to react to body movement. We have two methods of counteracting this in sim - **Killing CTM** and adding **IFG**.

CTM = "Current Transformation Matrix". For the *Coco* dancers, it was helpful to be able to kill a certain amount of translational and rotational motion that the simulator sees. The dancer was rotating very quickly and the skirt was flying too high, but after killing some rotation, it swung a bit lower.

IFG = "Inertial Frame Generator". This is another more simple method of killing extra body root acceleration, but it is easier to animate on and off. When Merida moves back quickly, her dress swings up very high by default. By killing some acceleration, we can control how high it swings.

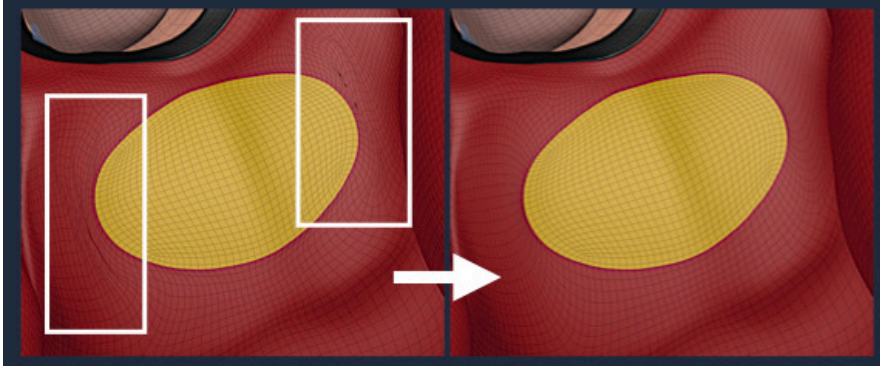
Post-Sim Fixes

- It is nice to do a lot of work in pre-sim setup, so that you can easily adapt and resim if the animation changes

- But once we get a reasonable sim, we can decide to start fixing and improving it in post. At this point it becomes more like hand animation.

- Common post-sim fixes include:
  - Relaxing cloth to smooth out unappealing lumps (types: relax, delta mush, patched-aware surface relax)
  - Sculpting cloth to hit shapes (brush sculpting, frame transforms, interactive sim sculpt, silhouette sculpt)
  - Warping cloth to the body or other objects
  - Filtering cloth to remove jittering
  - Using kinematic colliders to fake collisions

Post-Sim Fixes



Sides of logo crunching removed

Rest-mesh aware relax keeps logo graphic shape

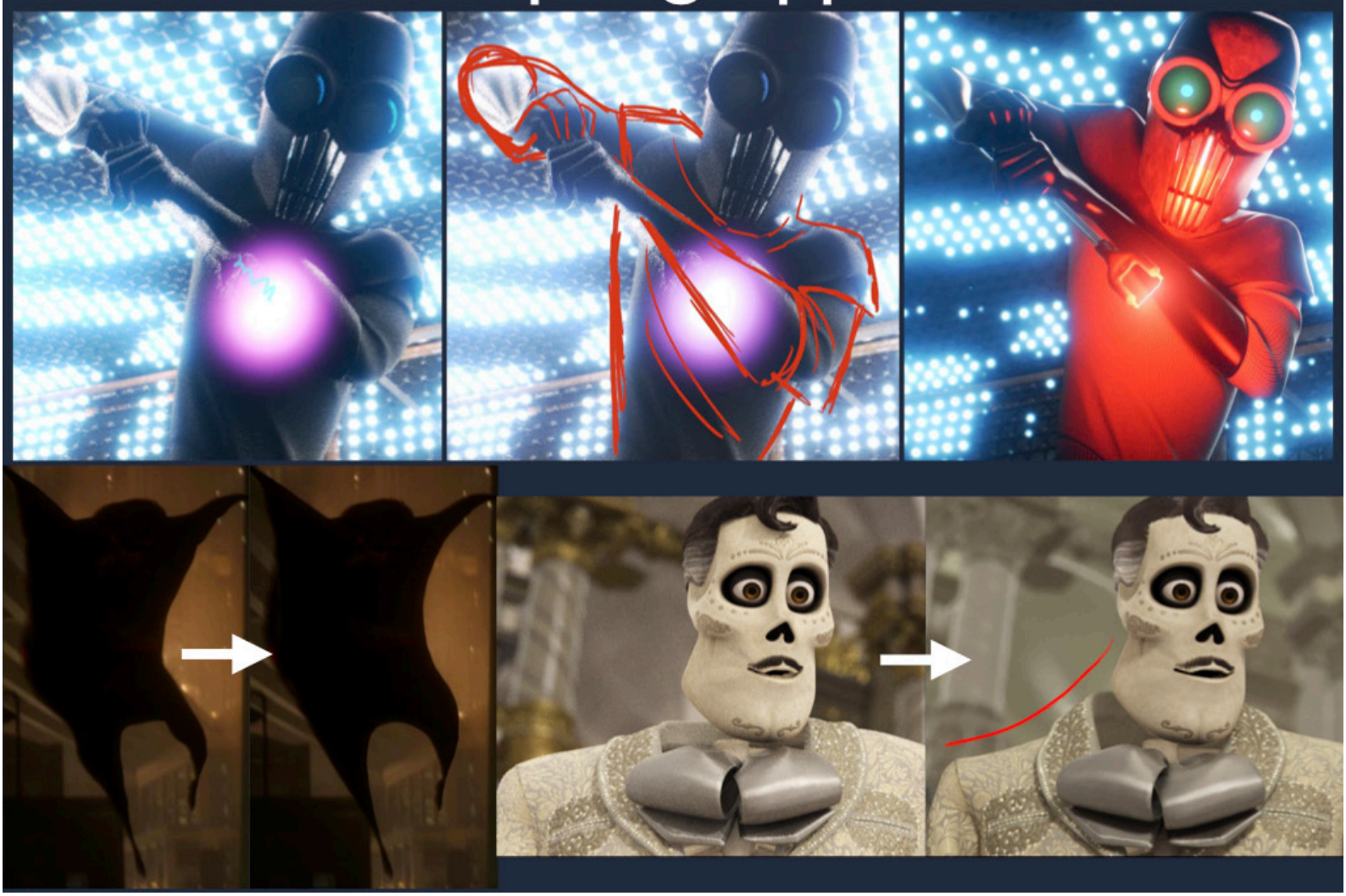
Patch-Aware Surface Relax

Unappealing folds removed

Along with the other tools developed on this show, Fernando de Goes wrote a new patch-aware relax deformer for rigging. We saw it had many uses for post-sim cloth cleanups, such as removing crunching while maintaining the surface, relaxing the logo without distorting texture, and removing unappealing folds for cleaner lines.

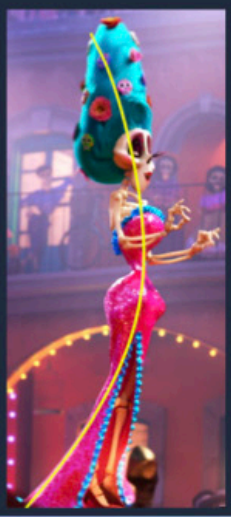
https://graphics.pixar.com/library/GeomtRelaxTalk/paper.pdf

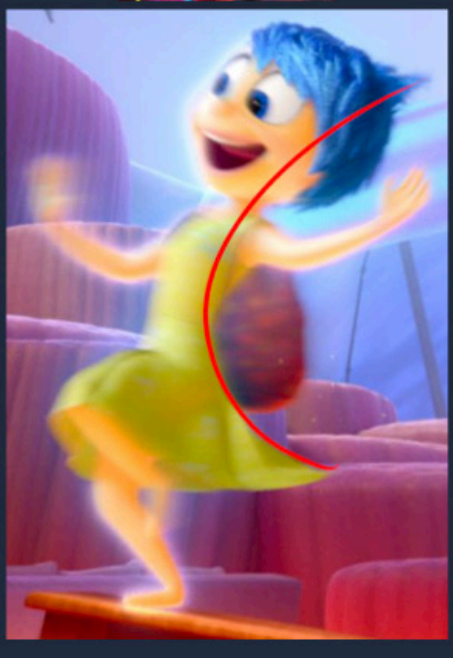
Sculpting Appeal



We are always looking for ways to improve the appeal and storytelling of our characters. With costumes, one way of doing this is with post-sim shot sculpting. We wanted Screenslaver to look scarier and more powerful than his original model, so we bulked up his upper body and mask with sculpts. Helen had to look sleek and elegant in her flying form, so we smoothed out arcs and tapers in her silhouette if the rig couldn't hit those shapes. Ernesto's jacket collar sometimes flattened out, so we sculpted it arcing upwards to lead you to his eyes.

Line of Action





Line of Action is an important principle in animation, and it is usually achieved with the body pose. Clothing can support and accentuate the line of action for more dramatic poses. The draping of Abuelita's apron follows the line of her body. The silhouette of Joy's dress extends the line from her chest to the tip of her hair. MC's dress silhouette is similar - long and elegant. Edna starts out startled that Jack-Jack is chewing her kimono, and the cloth creates an open curved pose. Then she pulls her kimono away and closes herself off in a sharp straight motion. Straights vs. curves!

Conclusion

- We've now seen several techniques Pixar uses to improve the correctness, efficiency, and beauty of the costumes.
- There is still a lot of potential growth in this field, and we are always trying to improve.
- Every show, we make new discoveries and improvements on the technology, artistry, and workflows.
- Although these tools are specific to our pipeline, we hope some of the concepts and workflow ideas were interesting and useful.
- And we hope more and more artists are inspired to pursue CG costume design, creation, and simulation!

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