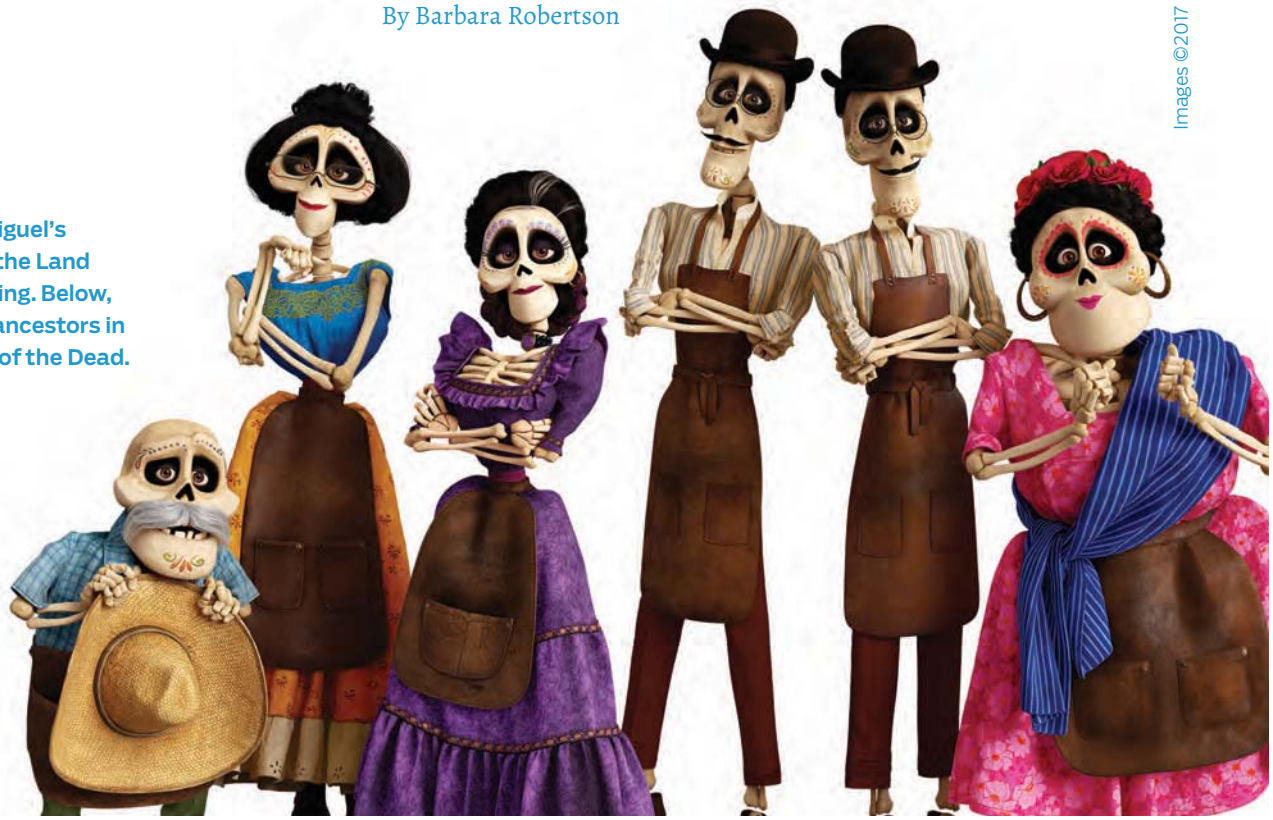
A NIGHT TO REMEMBER

Disney•Pixar's *Coco* honors Mexican culture with a joyful, heartwarming CG animated feature

By Barbara Robertson



Above, Miguel's family in the Land of the Living. Below, Miguel's ancestors in the Land of the Dead.

Once again, the skilled artists working at Pixar Animation Studios have exercised their expertise in computer graphics, animation, and storytelling to raise the art of CGI filmmaking with a colorful, unique, heart-tugging, joyful, and memorable film. The venerable studio's 19th animated feature *Coco* takes place during one day and night, a time known in Mexico as *Dìa de Muertos*, the Day of the Dead. If you think a one-day timeframe confining, you underestimate Pixar.

Disney•Pixar's *Coco* centers on Miguel, a 12-year-old boy in the fictional town of Santa Cecilia. Named after the patroness of music, the village was the hometown of the most famous musician in all of Mexico, Ernesto de la Cruz. Miguel, an aspiring young singer and self-taught guitarist, idolizes de la Cruz. But, the boy's family of shoemakers has hated everything related to music for generations – ever since Miguel's great-great-grandfather abandoned his wife, Imelda, and their family to pursue a musical career. Now Miguel secretly plays his homemade guitar in an attic hideout. That tension alone between Miguel's aspirations and his love of family might be enough conflict for some filmmakers. But, Pixar takes the story to another level, into a parallel world, the Land of the Dead.

In Mexico, on *Dìa de Muertos*, families remember their deceased loved ones who, legend has it, return from the afterlife to revisit their families. At least the ones who are remembered do. Family members place their ancestors' photos, favorite foods, and other items on an *ofrenda* (altar). When Miguel accidentally damages his great-great-grandmother Mamá Imelda's *ofrenda,* what might have been a simple coming-of-age story expands into another dimension. Mamá Imelda's *ofrenda* has Miguel's great-great-grandfather's face ripped out, and Miguel spots a guitar like that used by de la Cruz in a bent portion of the photo. If his idol de la Cruz is his great-great-grandfather, it might explain and justify Miguel's passion for music.

But, there's that family conflict to deal with. Miguel's grandmother (*abuelita*) destroys his guitar in a fit of anger. Still determined to enter a talent contest, though, Miguel breaks into de la Cruz's mausoleum to steal the lauded musician's guitar. In doing so, he sparks a transformation. Suddenly Miguel is visible only to those from the afterlife coming to visit their families, and he finds himself in the parallel Land of the Dead. Getting back won't be as easy. But, he must do so before morning.

"You always look for the ticking clock, the emergency, the place where the tension is," says Director Lee Unkrich. "We didn't have that at first. But, when we came up with the notion that the whole story takes place in one night and there was a deadline for Miguel, we had it. It made it more difficult to put character arcs though, but that was a challenge we could deal with."

LAND OF THE DEAD

Paying homage to the arches of marigolds and paths of petals typically seen in Mexican cemeteries on Dìa de Muertos, the filmmakers linked the two worlds in *Coco* with a magical marigold petal bridge. We see skeletons from the afterlife walking toward the Land of the Living, while Miguel with his loyal Xolo dog Dante go in the other direction, Dante rolling in the brilliantly illuminated orange petals.

"Effects created the bridge, and we built point cloud lights," says Danielle Feinberg, director of photography for lighting. "We could have the light centered around a single petal or have the petal glow; each petal has its own light. We could have an internal glow on the bridge and do bounce light on the characters. When the characters are walking, they can activate the particle lights for the petals anywhere they touch."

When Miguel and Dante look outward from the glowing orange bridge, they see the Land of the Dead surrounding them, far into the distance. Seven million blue lights sparkle on tall towers that extend through the depths of an immense darkness.

"When Miguel arrives in this magical new world, we wanted it to be an explosion of color and texture," says Harley Jessup, production designer.

In contrast to daytime and night scenes in the flat layout of Santa Cecilia, shots in the Land of the Dead all take place at night. Vertical towers representing layers of history fill the landscape. Mesoamerican pyramids at the base become Spanish colonial architecture as the towers rise, then more modern architecture, layers upon layers of history built as people arrived through the centuries. Giving the environment connectivity and a bustling life are elevated trolleys and gondolas that carry people from one tower to another.

The set designers began with crude outlines for the tower shapes that included cues to represent buildings, tracks to carry the trolleys, and streets that curved around the towers.

"We brought those early versions into Presto [Pixar's animation system] in a room where Lee [Unkrich] could move around and navigate through the 3D scenes using an iPad," says Chris Bernardi, sets supervisor. "He did some sweeping helicopter shots we hadn't envisioned before, and they ended up in the film."

Once the sets team had a good idea about the environments the director wanted to use for shots in the film, the team had to figure out how to build the individual towers and multiply them.

"We built the first tower, and the shape and structure was great, but we were missing the feeling of a neighborhood in

TROLLEYS MOVE RESIDENTS BETWEEN TOWERS IN THE LAND OF THE DEAD.

MIGUEL'S MUSIC

"As we were developing this story, we struggled with how to have Miguel articulate how important music is to him," says Lee Unkrich, director. "All our ideas fell flat. They were clichés. Or sappy. Or something a kid wouldn't say."

Adds Writer and Co-director Adrian Molina: "We knew Miguel needed to run from his family and risk his life, but in order for audiences to buy that this was worth doing, we needed to convince them that music was the air Miguel breathes. Our first idea was to have him say, 'Music is in my bones.' But that was intellectual."

Test audiences said they understood that Miguel loved music, but they didn't really feel it. So next, the team had Miguel sing about wanting to be a musician. But although that worked in the isolated sequence, it turned Miguel into a character in a musical, which didn't fit the film. *Coco* is filled with music, and music drives the story, but it isn't a classical Disney type of musical.

"So, we created a scene that gave us a new setting, a new frame of mind to work in," Molina says. "We put him in his secret attic space where he's free to be himself."

In this hideout, Miguel had created a kind of *ofrenda* for his idol Ernesto de la Cruz. It is here, in this secret room, where the 12-year-old boy passionately sings one of de la Cruz's songs.

"We can see Miguel experience his love of music," Unkrich says. "Doing this in a wordless way effectively communicated how much music meant to him."

the tower, places where we could actually shoot a film," Bernardi says. "So, we built crude shapes and crashed them together to form larger chunks and jammed those into neighborhoods until we could see our hero walking down a street."

In addition to wide views of the environment, the camera moves closer to show a grand central station, the department of family reunions, and a large stadium where Miguel will perform.

Throughout, representations of bones and skeletons appear in wood carvings, on doors, and also on a macro scale. In one shot, for example, two gondolas cross each other at the right moment to create a skull. Lights on the gondolas, in the windows, in streetlights, on plazas, on pathways, and elsewhere illuminate and define the environment.

A technique developed on *The Good Dinosaur* to manage the fireflies and upgraded to work with RenderMan RIS helped the lighting artists manage the seven million lights. Rather than calculating, for example, the color and brightness for a million streetlights, the code takes the calculation for one light and extrapolates that into the million.

"We used that for streetlights, lights in windows, and so forth," Feinberg says. "That way we could control all the lights with 12 or 15."

To place lights, the artists adopted a similar philosophy.

"We lovingly placed lights in 12 chunks of the environment and propagated them through the world," Feinberg says. "Then, this is the magical step, we had pockets we could change to any color and put wherever we wanted. This allowed us to highlight certain things and drop others back into silhouettes. The city drops back and we can see that it goes on forever."

Because Pixar uses RenderMan RIS, which is a path tracer, tricks like these helped reduce render calculation times.

"We leveraged the point cloud lights to pile in the lights without having a huge expense, but still with the flexibility to get what we needed," says Feinberg. "Also, [Senior Researcher] Christophe Hery worked on changes to the illumination model to make it faster."

LAND OF THE LIVING

Inspired by trips to villages in Mexico, Jessup designed Santa Cecilia with a somewhat muted color palette, muted at least in comparison to the rowdy colors in the Land of the Dead. We see Santa Cecilia's town plaza, the marigold petal paths to the cemetery where families decorate the graves, Miguel's multi-generational family's shoemaking workshop, and Miguel's hideout, sometimes in daylight, sometimes at night. Two-thirds of the film takes place at night.

"We could have gone desaturated for contrast [with the Land of the Dead], but we wanted to go for authentic Mexico," Feinberg says. "We have some bleached walls, chipping paint, and streets with fog, but it's a warm place. Where there are whitewashed walls, we put an orange light in the window. A kitchen in an outdoor scene has green fluorescent light. In the cemeteries, we have the totally spectacular candles, and we also have fluorescent lights from vendors in the market. In the daytime, the sunlight comes through painters' tarps and tints everything underneath. Lights in the distance turn into bokeh circles. It's total magic."

When asked about his favorite locations in the film, Bernardi picks two in Santa Cecilia rather than the intricate towers, bright colors, and brilliant lighting of the Land of the Dead. "I'm torn between Miguel's hideout and the *ofrenda* room," he says. "They sort of mirror each other. They're so much about people and a lot of love."

SKELETONS

In Santa Cecilia, Miguel's family includes his much-loved great-grandmother Mamá Coco, his papá and mamá, *tio* Berto his uncle, and *abuelita*, the family enforcer. In the Land of the Dead, Miguel meets great-great-grandmother Imelda, the source of his

family's music ban, and other ancestors.

All the people in the Land of the Dead – except Miguel – are skeletons. Skeletons wearing clothes.

"When you take the flesh off a character, you lose everything you use as a character designer," says Daniel Arriaga, character art designer. "We tried a lot of things to create variations of shape, and came up with the idea of having them wear clothes."

A second design challenge was in creating facial expressions on a skull.

We gave them a lower jaw that detaches, gave them eyes, and some have teeth," Arriaga says. They also drew eyebrows and added yarn hair. They broke Pixar's rule about staying true to materials.

"We committed to having eyelids and eyeballs, and a shaped socket for expressions," says Gini Santos, supervising animator. "We moved away from the jawbone structure and gave the skeletons lips for clear mouth shapes in dialog. But, they still suggest rigidity. We kept the line of the skull."

All told, 80 primary skeleton characters, each with 127 bones, populate the Land of the Dead. Animators experimented to find the rules for these characters, to determine how stylized to make the motion, to determine what holds the bones together and how far they can stretch that.

"We could push the spine against the rib cage like an invisible rubber band," Santos says. "We needed to determine how far we could go until it was unbelievable."

They started with walk cycles, picking the character Hector. Hector is a charming trickster who desperately wants to cross the marigold bridge but can't because no one has put his photo on an *ofrenda.* Hector promises to help Miguel find Ernesto de la Cruz in return for Miguel's promise to take Hector's photo back to his family's *ofrenda.*

"Hector's walk is inspired by Ratso in the film *Midnight Cowboy,"* Santos says. "It is a symbol of his brokenness. The looseness of his bones, the movement in his ribs added richness to his walk."

That "looseness" can extend for all the skeletons into an ability to drop their eyeballs into their jaws and to separate sections of their skeleton, even individual bones, and then join them again. Character TDs in the rigging department made it possible.

DEM BONES

"The animators kept requesting little bones, but I resisted that," says Christian Hoffman, characters supervisor. "I didn't want the shaders to have to deal with more bones. So, we created additional controls constrained to a space different from what the character was doing."

The rigging artists put that information on a separate layer so when a shot called for animators to blow a character apart, the animators could bring in additional rigging decoupled from the animation on the rest of the character.

"A constraint rig would track the location of a piece of geometry," Hoffman says. "It knows the world-space position and orientation of the geometry and can apply an additional matrix on the stack. That way we can have it ignore what the character is doing by swapping it out with a different space."

Animators had specific controls to move the bones around with extra looseness. With a "spread and roll" function, for example, animators could separate the rib cage from the hips yet still have control all the way up and down the spine.

"The trick, which is why we needed an additional rig to 'explode' the rig, is that the controls on the isolated parts follow the main movement," Hoffman says.

For dialog, the riggers added angles to the jaw to give the animators more control over articulation, and automated the way some parts of the jaw move.

DANTE

Dante, a Mexican Xoloitzcuintil dog and Miguel's loyal companion, follows the boy into the Land of the Dead. Like all Xolo dogs, Dante is nearly hairless, with only little tufts of hair on his body.

"There's nowhere to hide his wrinkles," says Christian Hoffman, characters supervisor.

Xolo is a street dog with no fat, so rather than volume simulations typically used for large, jiggly masses, the character team gave him secondary animation through skin simulations. As he moves, wrinkles form, particularly on his neck.

"He's a very unaware character," says Nick Rosario, directing animator. "He's a puppy in a dog's body. At first we treated him with too much of a thought process. We had to limit that. He's our most cartoony character, so we used more deformations, squashes, and stretches than for the other characters."

One of Dante's most cartoony characteristics is his tongue, which droops from the side of his mouth and flaps as he runs.

"His tongue is almost always exposed," Hoffman says. "Rigging it was a big challenge for us, but fortunately we had a good analogy: Hank from *Finding Dory.*"

PLAY THAT GUITAR

Communicating to the audience that the animated character Miguel was actually playing a guitar became a challenge for the animators and character technical directors.

"We knew that having him play the guitar right, having his fingers interact with the strings, would be one of our most difficult things," Santos says. "But, the director wanted it to look authentic."

Characters Supervisor Christian Hoffman asked Pixar Animation Supervisor and Short-Film Director Dave Mullins for help.

"I wanted to make it as easy as I could for the animators because this would be complicated," Hoffman says. "Dave plays the guitar. He gave me a whole packet of information."

The first step was to have a rigging lead develop an inverse kinematic system for the fingers.

"We usually don't set up inverse kinematics on the fingers because that gives us 10 new IK solvers, but I knew we'd need that for this," Hoffman says.

Next, they optimized the workflow for animation.

"If an animator positions the hand to play a particular chord on the fret board and wants to slide the hand, the fret spaces change," Hoffman says. "So, we automatically adjust the fingers. They get closer or farther apart."

The riggers also had the strings vibrate appropriately when Miguel strums the guitar.

"You can get really geeky about the vibration and harmonics, and we didn't go there," Hoffman says. "We have first harmonics. We don't go to second harmonics. But, in addition to strumming and string vibration, an animator could pluck a string and it would deform in a slightly linear manner. On the frets, when Miguel's fingers press down, the area above doesn't vibrate. If the string was vibrating when he presses down, when he lifts a finger, it would still vibrate. We had simple simulations the animators could fire off that would calculate the vibrations."

The ability to convince the audience that Miguel is actually playing the guitar helped particularly during the scene in which Miguel shows his passion for music.

"When I saw that, I thought, 'Wow,' that's a touchstone," says Darla Anderson, producer. "I love how quiet and simple that scene is, and yet it holds such depth, complexity, and emotional centering."

CLOTHES MAKE THE SKELETON

Because all the skeletons wear clothes, their costumes were as important in forming their silhouettes as their bones.

"We weren't bound by tissue for these characters," Santos says. "We were bound by what they wear."

Pixar can trace its research and development into cloth simulation back to little Boo's T-shirt in the film *Monsters, Inc.* Pixar's Fizt physics tool, originally developed by David Baraff and Andy Witkin, has evolved to accommodate the needs of subsequent films, but this film's bony characters and huge scope presented new challenges.

To illustrate, Emron Grover, simulation TD, shows early sim results – clothing snagged on a skeleton's knee, cloth bunched up around a bony hand.

"The cloth simulation was incredibly difficult," he says. "We needed a better collision detection system to solve cloth hanging in front of a collision sphere. It's an extremely mathematically difficult problem. There are hundreds of thousands of little triangles. The math could not figure it out."

To help iron out that problem, Pixar brought David Eberle, who had been at PDI, onto the team. Eberle, now a senior simulation software engineer at Pixar, created what Grover calls a continuous collision system. The system supports simulation of tetrahedral meshes with their invertible element model, allowing for coupled simulations between volume and cloth meshes.

"Fizt can do detangling, and that has made our simulator extremely robust," Grover says. "We wanted that ability in Eberle's continuous collision system. Eberle's system gives us almost flawless collisions – it's amazing what it can do. And on top of that, it's 100 percent faster."

To help simplify the calculations, the team gave each skeleton a collision body for the simulation. That particularly helped Hector, whose torn, unbuttoned jacket reveals the bones beneath.

"We fused the rib cage into one mesh but kept some detail between his ribs," Grover says. "Lee [Unkrich] and Adrian [Molina, co-director] wanted to see the bones, to feel the bones. So, we attach negative pieces of cloth that the cloth on top collides with. That makes the cloth on top stretch and not fall between the bones. We also fused the radius and ulna and the fingers, but we left the patella."

For Imelda, the simulation team used force fields to constantly push her dress outward and create her large shape. Similarly, forces created a fake trapezius, the large muscles in the back that move the shoulders on some skeletons. Cloth pillows filled negative spaces to create volume between bones.

"Usually, a character's musculature beneath the clothing creates the shapes we're used to seeing," Grover says. "But, we had large gaps."

TAILORS AND TINKERERS

To create the costumes worn by the skeletons in the Land of the Dead and the human characters in Santa Cecilia, tailors at Pixar created costumes in 3D but used 2D principles when they tessellated the clothing. They cut seams in the same places they would normally be cut in a 2D pattern.

THE COLOR OF BONE

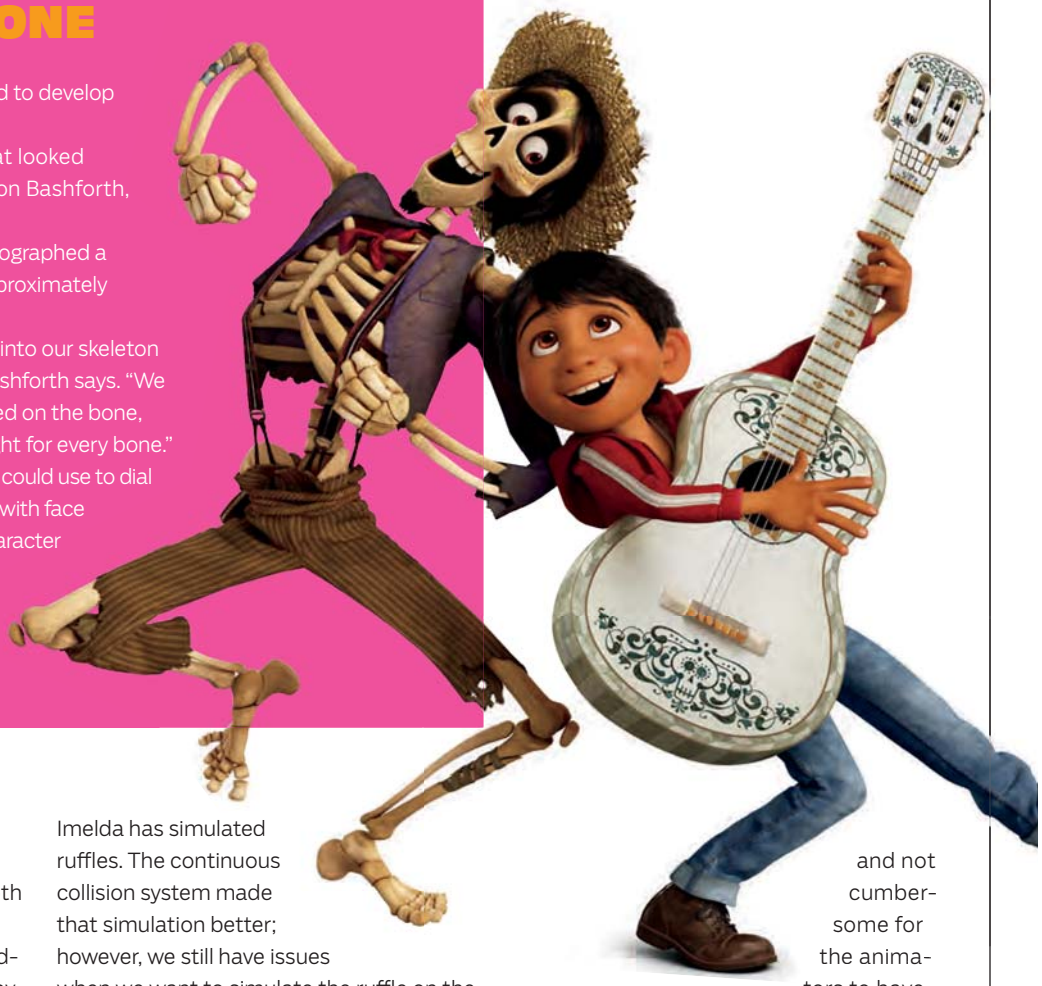
With 10,000 bones to paint, the team opted to develop software to help the texture artists.

"The challenge was to create bones that looked authentic without being creepy," says Byron Bashforth, character shading lead.

For authenticity, the shading artists photographed a variety of bones to assemble a library of approximately 16 textures.

"We plugged the photographed textures into our skeleton shader to layer the textures in bit by bit," Bashforth says. "We could control how and which textures landed on the bone, the color, the depth, and the response to light for every bone."

Also, the shading artists had controls they could use to dial the bones from old to clean-cut. That, along with face paint on the skulls helped distinguish one character from another in crowds, and added richness and complexity to the scenes. The artists could also swap colors and details, embossing, and glitter in the skeleton shader.



"The flatter we can get these panels, the more realistic they can be," Grover says, noting that Fizt and the shaders both use flat UVs.

For the dancers' big skirts, the team adopted an approach similar to the one they used for draperies in *Brave.* To construct the full skirts, they cut a circle into four pieces, separated them, and then inserted another piece between. Ruffles were still difficult, however.

"Some of the ruffles are just modeled; pasted, not simulated," Grover says. "But Imelda has simulated ruffles. The continuous collision system made that simulation better; however, we still have issues when we want to simulate the ruffle on the bottom of a dress. Our gathering system tends to scrunch up the dress it's attached to. We have some ideas how to fix that, but it's not solved yet."

To make it possible and not cumbersome for the animators to have the characters interact with the clothing, the simulation team worked with the tools team to develop a new gizmo called "simgrab." Simgrab constrains pieces of a garment in a specific location.

Miguel has 58 different costume variants,

PEPITA

Pepita is great-great-grandmother Mamá Imelda's spirit guide in the Land of the Dead. A folk art *alebrije* brought to life, Pepita is a fierce, brightly colored wildcat with the tail of an iguana, the wings and rear feet of an eagle, and ram horns.

"She has complicated shoulders," says Alonso Martinez, a character rigging artist. "Feathers, talons, and we can see every single tooth. It all had to communicate the same thing: This is a really strong character."

Pepita is also a light source.

"All the *alebrije* have patterns that glow," says Danielle Feinberg, director of photography for lighting. "We used a RenderMan mesh light to cast the light."

FINGER AND GUITAR STRING ADJUSTMENTS AND VIBRATION SIMS HELPED MAKE MIGUEL'S PERFORMANCE BELIEVABLE.

including a hoodie. Sometimes the hood is down, sometimes up. And, women grab onto those big skirts while dancing. Simgrab made that and more possible.

"It gave us so many more opportunities for specific performance choices," says Nick Rosario, directing animator. "If Miguel wanted to push up his sleeves, we could turn simgrab on, animate the sleeve, then turn simgrab off and his sleeve would stay there."

Similarly, animators used simgrab for Miguel's hoodie and to help him shove his hands into his pockets.

"We could put simgrabs on his hands and turn them on when he grabs the cloth to pull his hood on," Santos explains. "And, we had controls on his pockets so he could put his hands in and take them out."

The new continuous collision system and tools such as these helped the *Coco* team manage the enormous scale of this film.

"People ask me what the technical challenge is for the film," Unkrich says. "In this film, the challenge was the scale; about how to scale up all the work we had done already. We're at the point where we have figured out how to do anything, it's just a matter of the cost. We needed to populate the worlds with a lot of people wearing clothes. In the Land of the Dead, we have millions of light sources, so we had to find procedural ways to have those without someone hand placing every light. We grew the towers organically. All those details added up to a lot of work for a lot of people."

But, as with Pixar's previous films, that work will undoubtedly pay off. Prior to the film's worldwide release, the aggregate site Rotten Tomatoes had critics giving *Coco* an average 96 percent positive rating. Given that overwhelmingly positive critical acclaim, the film's family-centric theme and its joyful, heartfelt message, look for Pixar's 19th film to further expand the studio's list of much-loved box-office hits by one more.

"*Dìa de Muertos* is such a beautiful celebration," Unkrich says. "I hope this film will spark conversations and stories about their own family's ancestors."

Adds Molina: "My hope for this movie is that it will create a space for emotions in the same way *Inside Out* did for me. If audiences come away from the film with a desire to connect with tradition and with their generations of family, we will have done a good job." *Muy bueno.* ■

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ANIMATORS COULD SEPARATE AND REJOIN SECTIONS OF THE SKELETONS.