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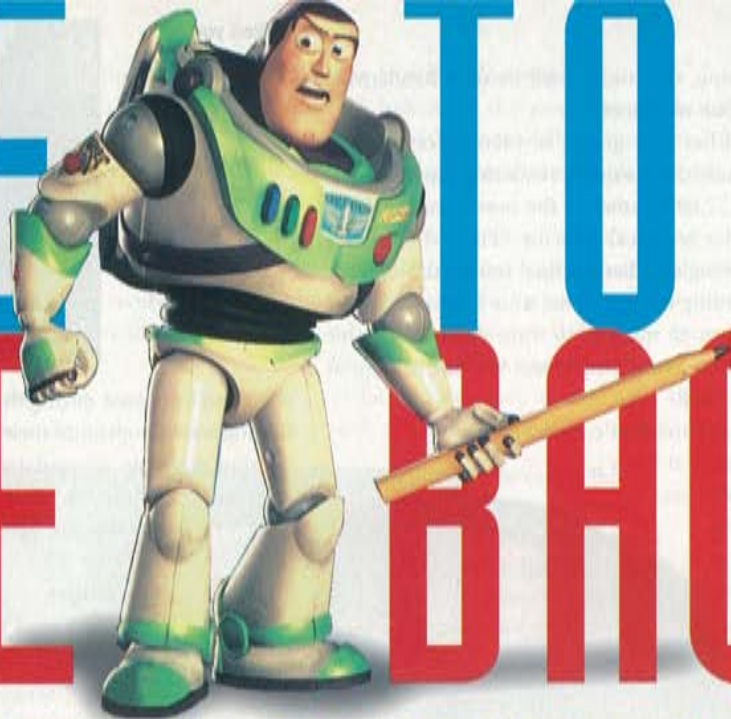


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THE TOYS ARE BACK



BY APPLYING TECHNICAL INNOVATIONS FROM PREVIOUS FILMS, PIXAR ADDS DEPTH AND DETAIL TO TOY STORY 2

It may not have made it to infinity and beyond, but *Toy Story*, the first feature film created with 3D graphics, has certainly made it into the filmmaking and computer graphics

history books. A critical, technical, and financial success, *Toy Story* generated more than \$300 million in box office revenue worldwide and over \$100 million in rental fees. The movie earned a special Academy Award in 1996, and turned Woody and Buzz Lightyear, the stars of the film, into household names. On November 24, Walt Disney Pictures and Pixar Animation Studios will release *Toy Story 2*, a sequel to their 1995 film. Directed once again by Pixar's John Lasseter and created at Pixar, the sequel brings back Woody, Buzz Lightyear, and the rest of the toys from Andy's room as well as the entire voice cast including Tom Hanks as Woody and Tim Allen as Buzz.

Sequels to Disney animations are usually created as direct-to-video releases, and that was the original intention for *Toy Story 2*. In fact, the video production was



Bullseye and Jesse show Woody what it's like to be a cowboy in *Toy Story 2*.

Behind them is a scene from the black-and-white TV show *Woody's Round-Up*, created, as are the characters, with 3D graphics.

well underway when the studios decided to switch to film. "The basic storyline about Woody being stolen by a toy collector stayed the same," says Ash Brannon, co-director with Lee Unkrich, "but it had to be restructured from an hour-long video into an 80-minute film."

The change gave the storytellers more elbow room for plot twists and turns, he says, but it also meant more work for the film crew, who had to reframe everything to accommodate film's wider aspect ratio and higher resolution, as well as cope with the additional 20 minutes and an increase in complexity.

"*Toy Story 2* is twice as complex as *A Bug's Life*, which was 10 times more complex than *Toy Story*," says Ed Catmull, Pixar's founder and chief technology officer, "and the production time was shorter." Pixar uses Alias|Wavefront's (Toronto) Alias Studio for modeling, Interactive Effects' (Irvine, CA) Amazon Paint for painting, and a host of custom software for such tasks as modeling, animation and compositing—all running on SG

BY BARBARA ROBERTSON

machines. For rendering, the studio used its own RenderMan software running on Sun machines.

Pixar's renderfarm has now grown to 1400 processors and even so, *Toy Story 2* pushed the studio's rendering capabilities to the limit. There are 122,699 frames in the movie, according to Thomas Jordan, render technical director (TD), who, with a team of 10 "render wranglers," herded final frames through the render pipeline. According to Jordan, the time it took to render each frame ranged from 10 minutes to three days, with frame sizes as large as 4GB. The fastest output was 930 feet of film, or 4,880 frames, in one week.

In addition to the problems of complexity, the artists and technical staff at Pixar faced two main challenges. One was in remaining true to the *Toy Story* world even though their filmmaking

is a 3D cartoon, in, toy collector of Woody, human-like mans in *Story*.



When you're only a few inches tall, you need to be clever to cross a busy street. It's tough and go, but Andy's toys all make it to Al's Toy Barn.



skills had improved during the past four years. The second was finding ways to optimize their work to meet an accelerated production schedule necessitated by the switch from direct-to-video to film. The story was completed this spring; animation was finished in August.

Toy Angst

At the root of the story is Lasseter's now familiar notion that toys are alive—when humans aren't watching. In the original *Toy Story*, an action-adventure buddy film, cowboy toy Woody rescues Buzz, the new space ranger toy, from the clutches of Syd, a nasty, toy-destroying kid. In the process, Buzz learns he is a toy. In *Toy Story 2*, the roles are reversed: Buzz has to rescue Woody. In the process, we all learn more about Buzz's space world and Woody's western world, and the toys learn more about themselves.

"To bring an inanimate object to life, you have to understand its function," Lasseter says. "Toys are meant to be played with by a child, and that's what toys want more than anything." Early in *Toy Story 2*, we see Andy accidentally rip Woody's arm then toss the broken toy on the shelf and leave for cowboy camp without him. Sharing the shelf with Woody is Wheezy, an asthmatic toy penguin with a broken squeaker, who has been abandoned to gather dust.

When Andy's mom drops Wheezy into the 25-cent yard-sale box and takes him outside, we understand how very wrong things can go for a toy. But in a daring maneuver, Woody rides bareback to the rescue on Buster, the family's dachshund, and saves Wheezy. Unfortunately, Woody falls off outside and, because the humans are arriving, has to freeze in place.

Andy's toys watch in horror as Al of Al's Toy Barn, a broker of collections, steals Woody, and this sets the stage for Buzz's due. Al has taken Woody to his apartment and there, Woody amazed to discover that he has a past: Woody was the star of a '50s TV cowboy show. Al has collected toy versions of the other toys from *Woody's Round-Up*—Jesse the cowgirl, Pete the prospector, and Bullseye, Woody's horse—along with tons of memorabilia like lunch boxes, comic books, record players, hats, and so forth. With Woody added to the collection, it's complete, and Al takes everything out of storage. That sets up the conflict: Will the nicely repaired Woody stay with his new friends so the collection can go to a museum where

he will be taken care of forever? Or, if Buzz and Andy's toys arrive in time, will Woody come back with them, at the risk of being abandoned by Andy? This is an animator's dilemma," says Glenn Queen, supervising animator, who led a team of 66 animators. "Every scene has gold."

For the animators, many of whom worked on the first film, one of the most difficult scenes in *Toy Story 2* was the first one, according to McQueen. "Because we had Woody and Buzz every day, the temptation is to break the mold. But the first time the audience sees the characters, we have to be sure that we've caught the essence of the characters and that there is nothing tricky about the performances," he says.

Similarly, the familiar characters had to look like they did four years ago—as did the *Toy Story* world. Yet, during those four years, Pixar had used the short film "Geri's Game," starring a character who was arguably a technically and artistically better human than those in *Toy*

Story, and the studio had created a second feature film, *A Bug's Life*, in which far more complex lighting and shading models were used to create a visually richer environment than in *Toy Story*. The trick was to use the improved technology selectively. *Toy Story 2*'s new human, Al, for example, is more complex than Woody and Andy; however, Mom and Andy have been improved. The standard line at Pixar is that Mom's got a new wardrobe, a new "do," and has been working out—but she still looks like Mom. "We didn't set out to produce the perfect realistic human," says Lasseter. "The humans are still cartoons." But even so, they're more realistic than the humans in *Toy Story*—particularly, Al.

The Human Element

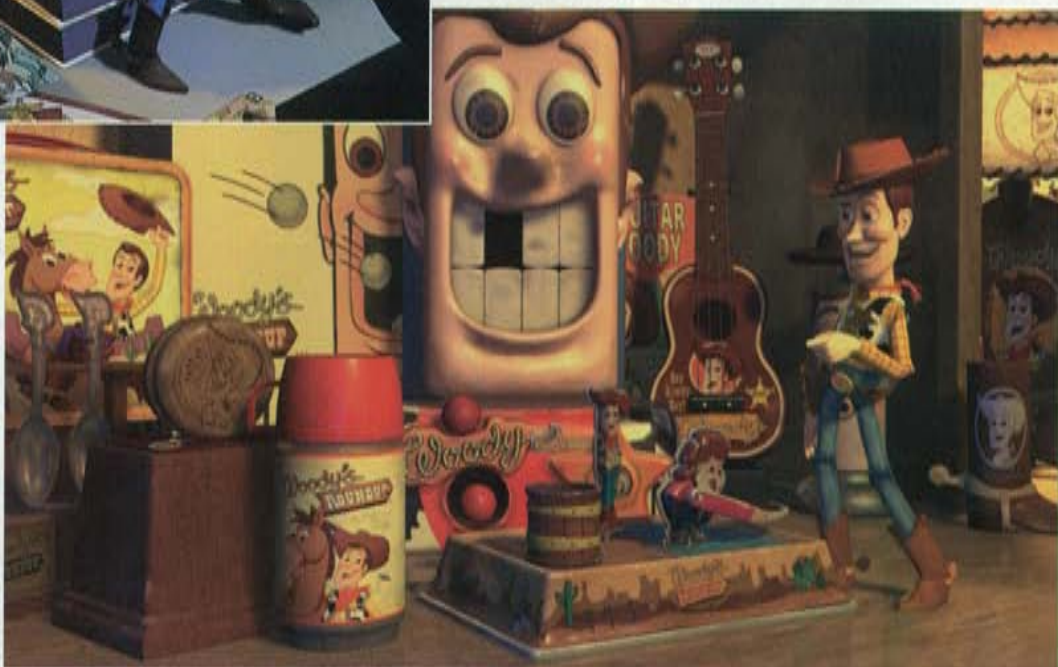
"Al's hideous in this great way, and he's a very complex model," says Eben Ostby, modeling supervisor. "If I had to make a rough guess, I'd say that all the source files that make him up come to 200MB. Woody is about a tenth of that."

As in "Geri's Game," Pixar's technical directors used subdivision-surface technology to help create the skin for Al and the other humans. But rather than try to simulate the physical properties of skin, as they did for the humans in the original *Toy Story*, they applied what they learned from *A Bug's Life* to create surface texture. "We learned what shaders and painters can do well, so rather than model the skin physically, we created tools



To create the light shining on Woody's face and in the room, Pixar emulated the particular color of light emitted from a black-and-white TV set in the '50s.

for the painters," says Brad West, shading supervisor. More specifically, the TDs developed a giant RenderMan shader that could create such skin characteristics as pores, blotchiness, veins, shininess, sweat, and so forth, and even whiskers



If you look closely, you can see yellowed printed material, little scratches, and paint worn off metal surfaces that tell you this collection is old but well-maintained.

that the shader could grow procedurally. Those individual characteristics became the painters' tools when the TDs added them to the Amazon Paint interface.

The painters started with a basic rendering of the model, then painted layers on top to fine tune the rendering. Al has the most detail, but because they didn't want Al to look too different from the other humans, they also added detail to Mom and Andy. "We just don't have the camera get as close to them," West says. "My favorite part of Al is his whiskers," he adds. "He has a five o'clock shadow, his skin is blotchy, and in one area he has a small scar where there are no whiskers. He even has white-



Planning Woody's rescue while Rex, Slinky Dog, Mr. Potato Head, Hamm, Bo Peep, and other toys from Andy's room look on is Buzz Lightyear.

heads." To create the lines under Al's eyes and around his mouth, the painters used displacement shaders. To create the hair on his arms, the TDs used geometry.

Pixar used two different techniques to create hair. For hair on rigid surfaces such as a human's skull, Guido Quaroni, a TD on the human modeling and shading team, created an Alias plug-in. The plug-in gave the TDs guide hairs made of geometric primitives that they could use to describe the look and movement of thousands of hairs when rendered. For hair on deformable surfaces like Al's arms and the dog, the painters used texture maps.

To create clothes, the TDs chose to sculpt cloth into position rather than use a dynamic cloth simulation. "The research department was still working on the simulator for "Geri's Game" when we started," says Oren Jacob, associate technical director. "Geri is a skinny old man wearing a baggy jacket. Al is a fat dude with clothes stretched taut, and he was going to be in many more shots that Geri." So, they decided to model the creases and folds for certain poses, then use shape interpolation between the changes in position. "All the animators had to do was animate the model and the clothes would follow," Jacob says.

"We have tons of geometry in this film," says Galyn Susman, supervising technical director. "In *A Bug's Life*, the complexity was in the surfaces. In *Toy Story 2*, the complexity is in the geometry." She notes that two of the most geometri-



To keep a crisp leading edge on the glowing energy balls being fired at Buzz by his archenemy, the evil Emperor Zurg, the effects team blurred the objects one-half frame backward in time.

cally complex scenes take place in a downtown area and in an airport.

"Downtown is extra heavy," agrees Jordan. "Every block had 10 trees or more, every tree has thousands of leaves, every car has one or two people, and every person has thousands of hairs." Then there are buildings, grates, stoplights, and parking meters. The buildings have facets and windows with dirt on them. "None of it is fake," says Susman of the downtown scene. "It's all geometry. Sure we could have painted it, but we've been keeping the camera very fluid. Once you move the camera, even a little, the trained eye knows something is wrong."

All this geometry helps make scenes visually complex, but it's the way in which the models interact

with light that makes them visually rich. "We used a lot of techniques from *A Bug's Life* that help the lighting create visually richer scenes," says Ostby. "We rounded edges to create a place that catches light and we avoided making things that are too flat—even for the background props."

"We've rewritten the way surfaces and lights talk to each other, and we used the new tools and processes from *A Bug's Life* to improve this movie artistically," explains Sharon Calahan, director of photography. "We think cinematically, yet we're also in the illustration world. We create physics and make a believable world, but it's not real. We want painterly influences, but we don't want to flatten things out. We want spaces that look deep. We're evolving our own studio look, and that's the fun part. I think that overall, this film is softer and has more depth than *Toy Story*. But I still hope it feels like the original."

To create *Toy Story*, the studio used 366 objects. In *Toy Story 2*, there are approximately 1200 models that range in size from a pencil to an airport—plus variations, according to Susman. For the human "extras," the modelers mixed and matched pieces from about a half dozen models. "We'd put different faces on the same body and vice versa," says Ostby. To help the animators create performances for the extras, the R&D department developed new articulation controls for

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he models. Called "Geppetto," the software, which was written by senior scientist Tony DeRose and graphic software engineer Dirk VanGelder, evolved from Pixar's proprietary "PET" (Patch Editing Tool) technology.

"Geppetto is a way of grouping points and tying an articulated variable to them," explains Susman. "It gives us a way to build armatures and transfer them from character to character and to define what happens procedurally." With Geppetto, a modeler could import an entire armature to another human, and it would need only fine-tuning to accommodate different sizes.

Special Effects

This attention to detail is evident in the effects, as well. For example, Pixar created clips from Woody's TV show using 3D computer graphics. That animation was rendered in color, converted to NTSC black-and-white video, then run through a compositor to add litter, negative scratches, hair, coffee stains, scan lines, video bloom, and static—everything that might have happened to a Kinescope created for television in the '50s. The result was mapped onto a CG model of a Philco TV set, then warped to fit the screen. "We went through all the stages as if the show had been created with the old process," says Jacob.

Even the dust on Wheezy's shelf is created carefully. "We could have used particle effects to create dust, but we didn't



Lighting conditions in *Toy Story 2* range from bright daylight to nighttime scenes such as this one in which Buzz and the toys race to Woody's rescue in a Pizza Planet truck.


thick crust of dust that's spongy," Jacob says. "It has an internal structure." So when Woody puts his hand into the dust, the dust compresses, and when he lifts his hand, the dust sticks to it. The effects team also created dust bunnies using a volumetric structure. "We put them in the model catalog so the layout department could place them where they wanted," says Jacob.

Some of Jacob's favorite effects shots, though, were created for the space sequences—explosions, shockwaves, and crowds of robots. "In one shot, Buzz is surrounded by 280,000 individually articulated robots all shooting at him at the same time," he says.

"One of the successes of *Toy Story* is that toys are great subject matter for 3D animation," says Lasseter. "You can put in details you couldn't do in hand-drawn animation: stickers, seams, rivets, screws, clear helmets, plaid shirts, and denim jeans."

To help deal with that detail, Pixar developed many schemes for optimizing the production, including, for example, automatically generating details depending on how close a model is to the camera. "A human might have 200,000 hairs, but if the camera is very close or very far away, you only need to use 500," says Susman. To help a tired crew at the end of production, and to have more control of the final product, Pixar is working on digital color timing. "When we did the first *Toy Story*, we had the idea that once we were in production, we wouldn't change software," Catmull says. "It turns out that's incorrect. We have to change. So we worked out methods for allowing that change."

"At Pixar, technology is developed in service to story," says Lasseter. "I think people will be surprised at this story. The humor and adventure from the first *Toy Story* is there, but the level of emotion that especially Woody and Jesse go through is deeper. The things that prevent toys from being loved are being broken, lost, and stolen, but the most difficult is being outgrown. We get to see that from a toy's point of view."

It's true that toys are usually outgrown, and technology, for that matter, is outgrown, too. But stories can live forever. 

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Covered with dust, Wheezy tells Woody that he's been forgotten. The dust is geometry, not a particle effect.

think it would be convincing," says Jacob. "Instead, we decided to stick millions of pieces of stuff in the shot"—2.4 million pieces of stuff, to be precise, including tiny "hairs," two-to-three pixel-wide flecks, and little spheres. "The shelf is covered by an 1/8-in.-