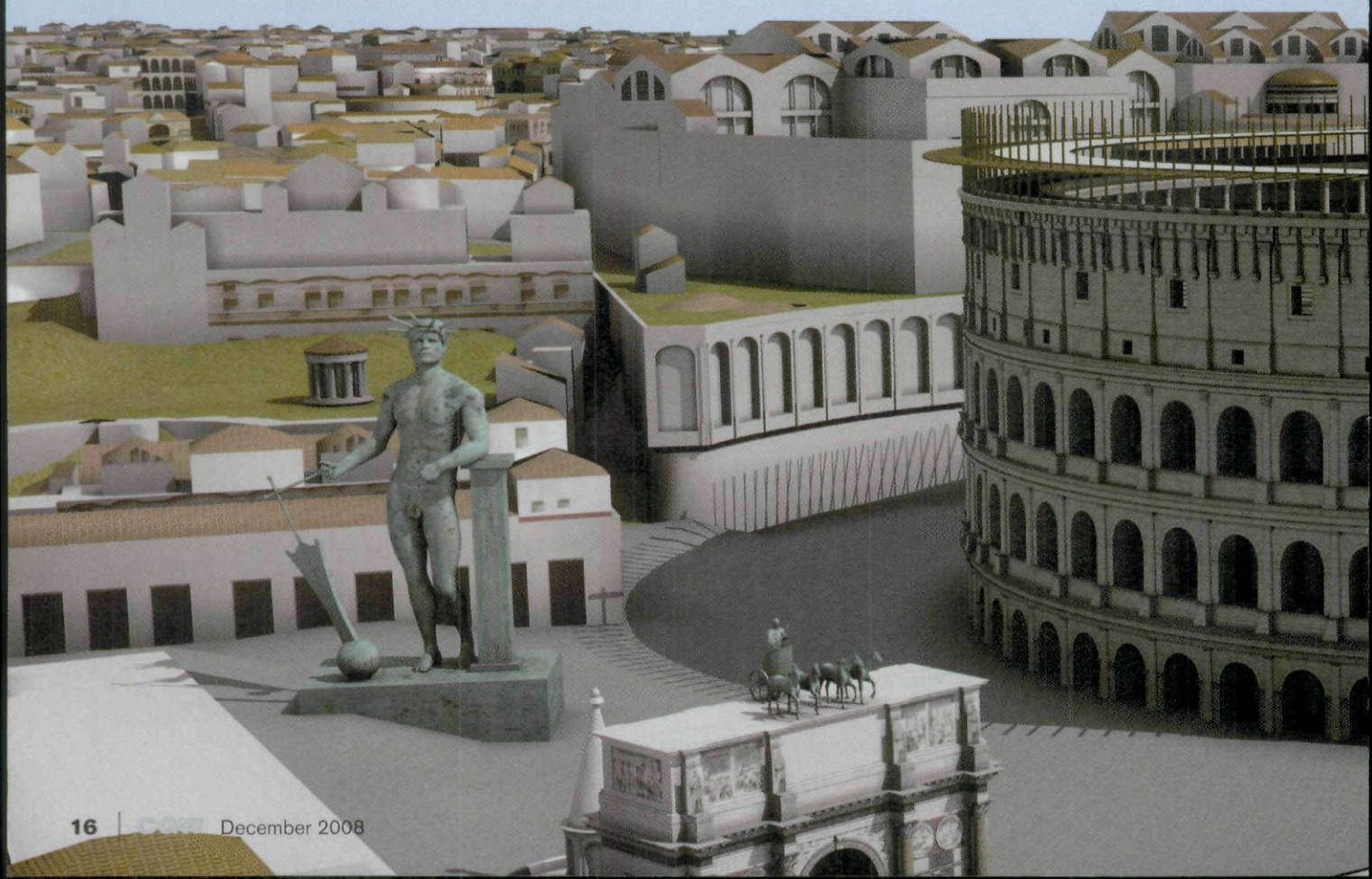
HISTORY IN THE MAKING

SCHOLARS AND MODELERS ACCURATELY RE-CREATE ANCIENT ROME AND MAKE IT ACCESSIBLE VIA THE INTERNET

BY KAREN MOLTENBREY



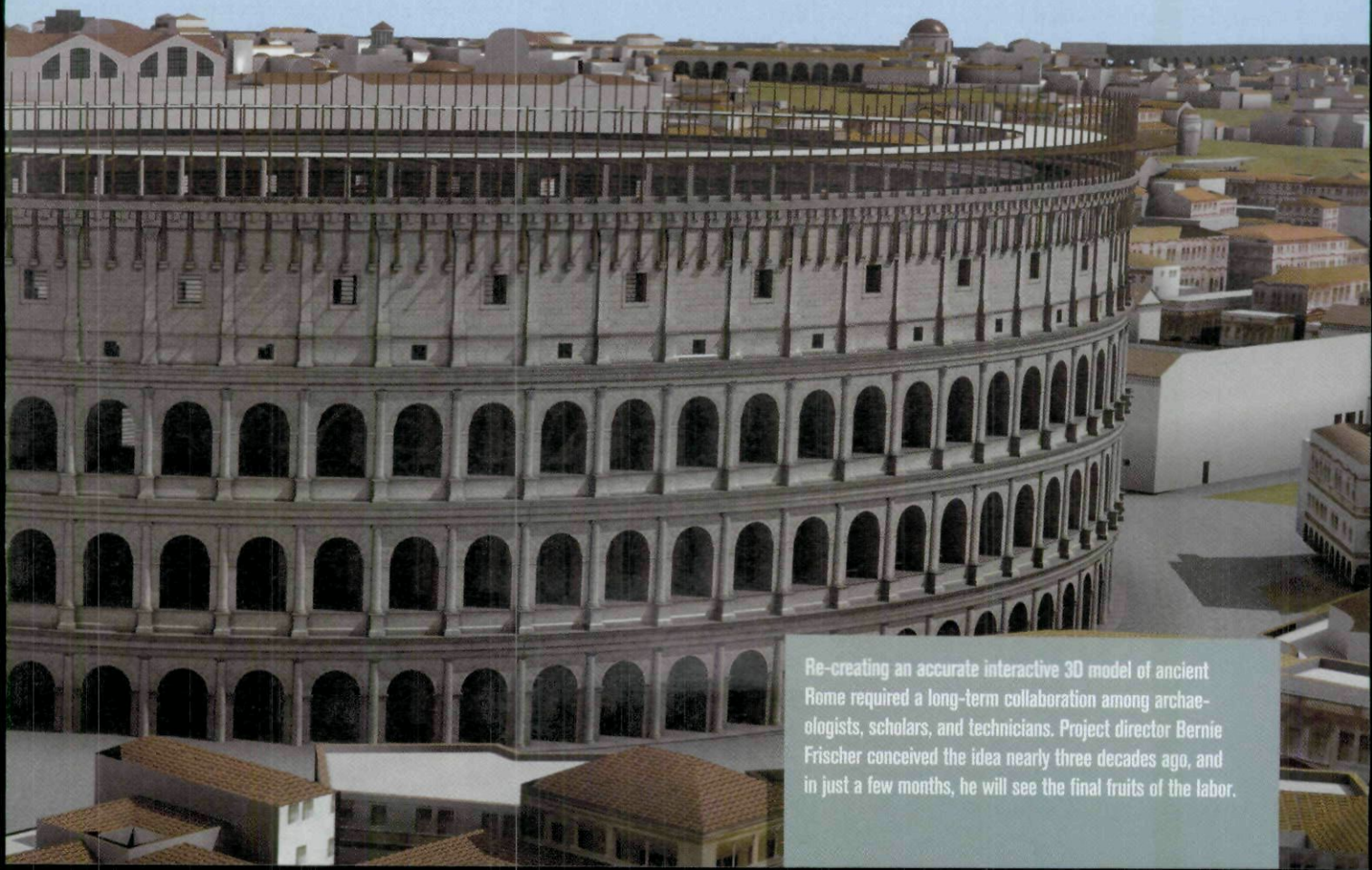
ROME—one of the great cities of Western Civilization and the capital of the Roman Empire—was not built in a day; it expanded and evolved over centuries. Even when an international group of archaeologists, historians, and CG technicians completes its work on an interactive 3D digital model of ancient Rome at the peak of the city's development in 320 AD, the project will have taken far more than a single day—hundreds of days, actually. Yet, the feat, even by today's standards, will be impressive nonetheless.

Rome Reborn 2 is interactive, enabling the user to select the viewpoint while exploring the area.

The historically accurate digital re-creation—which melds the wondrous technological achievements of the past with those of the present—offers a comprehensive, holistic perspective of this amazing city. The most impressive aspect of this re-creation is the sheer scale of the model: It encompasses 7000 carefully reconstructed, detailed period buildings covering 10 square kilometer (3.86 square miles) of authentically contoured landscape. And when this virtual model is completed in the spring of 2009, users will be able to explore the ancient cityscape, structures, and alleyways in real time and in high resolution. What's more, all the imagery and information will be rendered interactively within the user's Internet browser.

Accomplishing such a Herculean virtual building project required a number of CG innovations, not only in modeling and rendering, but also in the management of enormous datasets and the ability to easily update and display such information. Also noteworthy is the fact that Rome Reborn 2 will establish a new form of scholarly communication, and its technological innovations can be used to further modern-day urban-modeling projects.

"Rome has a long and interesting history," says project director Bernie Frischer, "though the city's reign as the cultural and political center during the height of the Roman Empire knows no rival." Two thousand years later, archaeological evidence of this period is present throughout the city: a nearly perfectly preserved Pantheon, a partly destroyed Colosseum, remains of ancient city walls, arches, public meeting places, palaces, and more. Yet, an



Re-creating an accurate interactive 3D model of ancient Rome required a long-term collaboration among archaeologists, scholars, and technicians. Project director Bernie Frischer conceived the idea nearly three decades ago, and in just a few months, he will see the final fruits of the labor.

unearthed monument here and remnants of an ancient statue there—often miles apart from one another—can only offer a snapshot of the past; it hardly provides an expansive, detailed picture. Rome Reborn 2 promises to do just that.

Rome Revisited

Without question, the Rome Reborn 2 digital model is impressive and groundbreaking on a number of fronts and is the largest virtual reconstruction, cultural heritage, and digital archaeology project to date. But to truly appreciate this landmark in terms of its historical and technological achievements, we first need to step back in time—not to the days of Constantine the Great and the Roman Empire, but to the 1970s. That's when Frischer, a young academic, first became enamored with the city and its history after winning the Rome Prize at the American Academy in Rome.

"That changed my entire life," says Frischer of receiving the postdoctoral fellowship for young artists and scholars. "The intention is to soak up the atmosphere of Rome, and I certainly did that."

At the time, Frischer had a PhD in classical arts and literature, and wanted to learn about archaeology. He got that chance when he joined one of the academy's professors on a walking/talking tour of the city. The starting (and eventually ending) point for this journey was at the Museum of Roman Civilization, which houses the Plastico di Roma Antica, a physical model of ancient Rome.

The historically accurate model was crafted over a 40-year period beginning in 1933 by model makers working for the city under the direction of archaeologist Italo Gismondi. As new discoveries were made, they were incorporated into the model. When construction ceased in 1973, a year before Frischer first laid eyes on it, the 1/250-scale model measured 60 feet across and was viewed from a balcony above.

"It was considered as accurate of a representation of Rome in the 4th century AD as the evidence permits us to reconstruct," notes Frischer. The model, like its eventual digital iteration, is based on information garnered from excavations and archaeological data.

Images courtesy Procedural.

(Top) To bring Rome back to life, "everyday" structures were added to the cityscape, augmenting the main pieces, such as the Circus Maximus, shown here to the right. (Below) This close-up offers a detailed look at those structures, which also were crafted based on historical data.

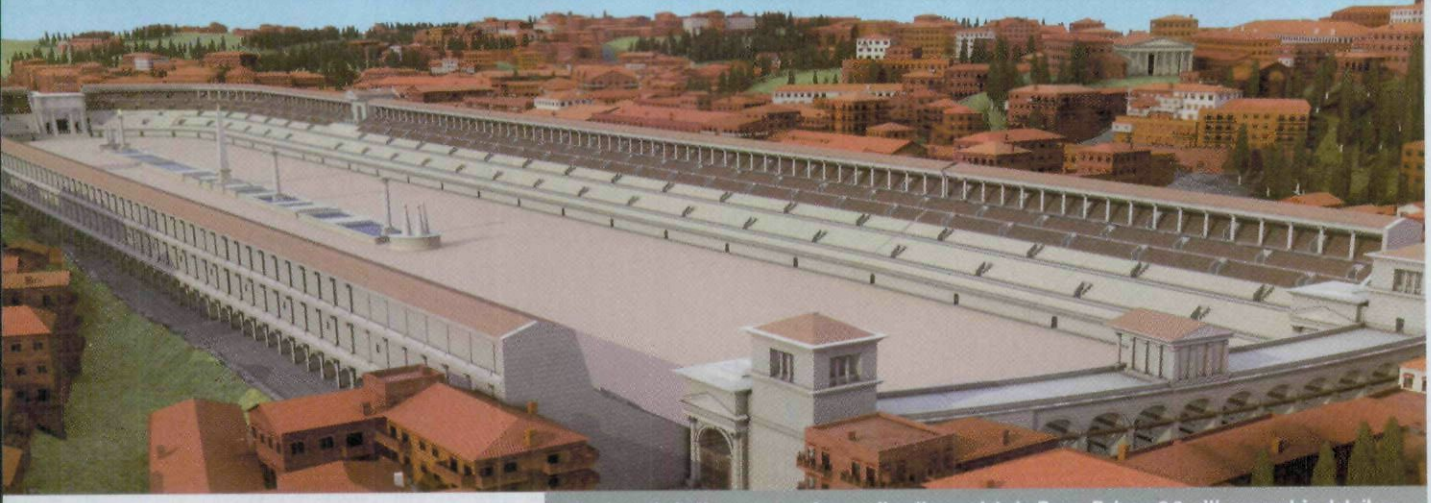
Today, the model itself is considered a historic monument, and when viewing it, "visitors get an integrated vision of what Rome looked like at its peak during the Roman Empire," explains Frischer. "When people see it for the first time, their breath is knocked out of them. The beauty and the scope is astonishing—it was a city of one million-plus people, with 7000 buildings."

The impact of this museum piece certainly was not lost on Frischer. With his background in both the sciences and the arts, he began to wonder if there wasn't some technology that would figuratively take this monument out of its fairly obscure museum in the suburb of Rome and place it in the hands of the general public and classrooms around the world. "The obvious way to do so at the time was through 35mm photography, which meant taking a lot of pictures and slides, which I did," he says.

An Evolution of Ideas

After leaving Rome, Frischer began teaching at UCLA, where he remained for 28 years. While there, he shared his photos with colleagues in related fields. Yet, he continued to seek a better, more encompassing solution for publishing the Rome model, in all its integrity, as a whole, not as a series of parts. "A slide provides a fixed view, a single component. I wanted to capture the scope and grandeur of the model by moving around seamlessly from one item to the next in the city," Frischer explains. A seed was planted in his mind after talking with Donald Appleyard, an urban planner who also just happened to have been a senior resident at the American Academy, as well.

"At the time, Donald told me about a process being developed at the University of California, Berkeley for city planning, whereby physical models were videotaped and then added into general video shots of the city, showing how the building would look in that location," recalls Frischer. "We discussed how this approach could be used for the Rome monument." That was in the 1970s, and over the decades, the solution



The team is in the process of upgrading the models in Rome Reborn 2.0 with geometric detail as opposed to baked-in textures. Each model will average approximately 10,000 polygons.

would change and evolve—thus showing that all roads do not lead to Rome, at least not the one Frischer envisioned.

In the mid-'80s, Apple Computer almost sponsored the creation of a videodisc containing imagery of the monument. The plan called for Frischer and his group to maneuver a tiny robotic camera through the physical model. However, the model lacked a certain amount of detail. "The doors, windows, and columns had detailing around the edges and included all the parts, but most of the walls and surfaces were plain," recalls Frischer. "As you go down a street and look at the facades, you see non-differentiated white plaster. It just didn't look like a street."

That was because of a POV issue. Like today's digital modelers, the physical model makers had taken shortcuts by adding detail only to the areas that would be visible—in this case, from the viewing area above. Because of the disappointing results, the disc was not made. But for Frischer and his group, the revelation was a turning point. "I realized that if we wanted to make a digital model of Rome, we'd have to start over from scratch," he says.

A few years later, Frischer consulted on an exhibition that integrated works of art from an ancient site into a 3D reconstruction. Identifying an opportunity, Frischer suggested the Forum of Trajan in Rome. "We placed the remains of the forum into a gallery and then projected a 3D model of how it actually looked onto a screen," he explains. This introduced Frischer to real-time 3D modeling software, in this case, Creator from MultiGen-Paradigm (now owned by Presagis). Unlike other 3D content-creation software, such as Autodesk's Maya, Creator allows the modeler to input exact architectural measurements—a valuable building block for digitally re-creating Rome.

Confident that he was now heading in the right direction, Frischer consulted with Bill Jepson, whose Urban Simulation Lab at UCLA was devoted to making a large city model of contemporary Los Angeles. "Bill had the right lab, with the right hardware and software, and the right know-how to make a model of any kind of city—contemporary or historical," says Frischer, who eventually set up his UCLA Cultural Virtual Reality Lab in 1996.

'Empirical' Modeling

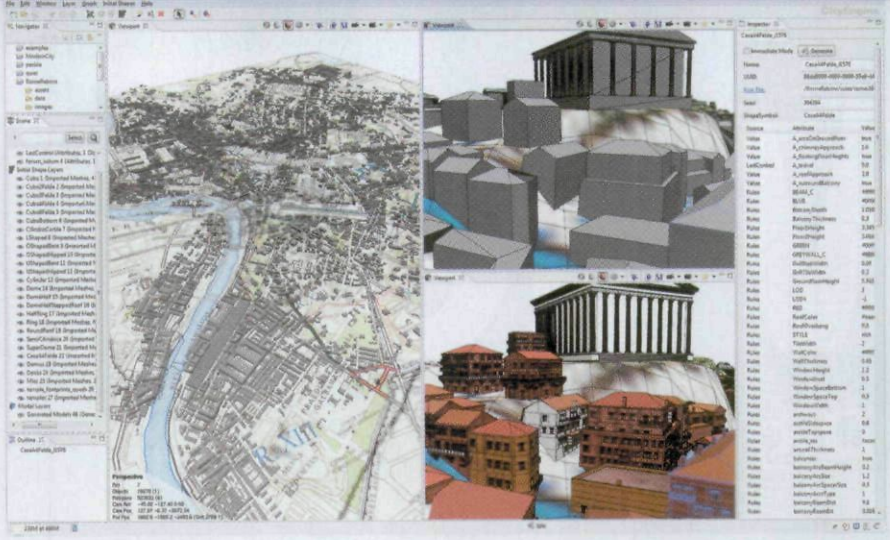
And with that, ancient Rome was on its way to being digitally reborn, though the effort would prove to be no Roman holiday. The team's approach was to start at the city center—the Roman Forum—and work outward in concentric circles to the city walls. "To make this a high-quality work, we had to get peer contributions from scholars who have spent years studying ancient Rome," Frischer says. He points to what he and others consider a not-so-successful re-creation of Pompeii in the 1990s by Carnegie Mellon's Sim Lab: The group had the proper equipment but didn't work in conjunction with archaeologists, and while the model looked great, it lacked authenticity.

"We decided the archaeologists should run the show, and the technologists would be at the service of the archaeologists," Frischer adds. "As it turned out, many of the technologists were young scholars, spending their summers studying archaeology and conducting field work."

Construction began on the Roman Forum and the Colosseum, as the modelers crafted the building using Creator. For rendering the textures, they used a radiosity-based method of baking in the lighting solution. The models looked high quality for the time, but they appeared to be floating in space, with no context. "We decided to build up some context with an elevation map and filler architecture in the landscape, to make the two structures look like part of the urban fabric," says Frischer.

This brought Frischer back to the Plastico di Roma Antica model. Professor Gabriele Guidi from Milan headed a team that digitally scanned the monument. Ideally, they would have placed laser scanners or photogrammetry equipment on top of the physical model. Because that was prohibited, the crew had to conduct the scan from the balcony of the room. While the resulting mesh was accurate in terms of reverse engineering, it was not appropriate for VR applications because of the subtle distortions in the geometry, resulting from an interaction of the noise from the scan process and the scale of the physical model—any error was multiplied by 250, the scale factor.

"When you looked at the results up close, they were terribly distorted and warped,"



Images courtesy Procedural.

Using Procedural's CityEngine software, the group is upgrading the general structures with high-res models in record time, freeing others to focus their attention on the unique monuments.

Frischer recalls. "Arches that should have been rounded were oval-shaped or worse."

At the time, there was no algorithmic method of correcting those distortions using standard post-processing tools. So, two of Guidi's grad students developed a solution that would crawl through the scan data looking for repeated geometric forms based on volume and form. "I assumed that Gismondi's team had created the physical models using repeated elements," says Frischer. He was correct: 99 percent of the buildings correspond to 38 simple forms, and when mixed and matched, created the impression of extensive variety.

Using Maya and Creator, the group crafted new handmade models from digital versions of the forms, and then several of Guidi's students began the process of swapping out the messy scan data for the clean models. Textures were painstakingly applied by hand. Interactivity was added to the overall model via MultiGen's OpenFlight.

In June 2007, Rome Reborn 1.0 debuted. It featured two classifications of buildings: Class 1, which are supported by hard data and reconstructed with 100 percent accuracy; and Class 2, buildings and infrastructure, like bridges, canals, and roads, that archaeologists know existed but can only approximate their location and aesthetic. Nearly 300 components of the city were Class 1 models, but Frischer's team had the time and funding to re-create only 31 of them with full detail. So many Class 1s, along with most of the Class 2s, had textures but lacked architectonic detail. Some surfaces didn't even have textures.

"The results were acceptable when seen from afar, but do not support a close view, as happens in a virtual-reality session when you want to simulate the experience of walking down a Roman street," says Frischer.

At a total of nine million triangles, the version contained a number of fill-in models, basic geometric building forms with some texture detail; these were intended to supplement the main pieces, including the Forum and Colosseum. Painted vertexes atop virtual terrain maps gave the cityscape life.

Furthermore, Rome Reborn 1.0 was mobile; it ran on a suped-up Shuttle workstation with an Nvidia 8800 card, enabling the user to move around the model at 20 frames per second. Impressive? Yes. But aside from the basic fill-in models, there was another component missing—it could not be published via the Internet as a real-time interactive model.

Rome, In All Its Glory

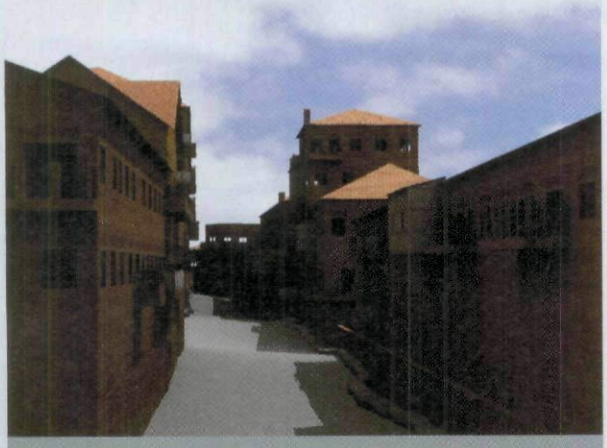
Not resting on its laurels, the group continued to pursue Frischer's ultimate goals for the project. The crew's first objective with Rome Reborn 2 was to upgrade the detail and resolution of the structures. Frischer had recalled hearing about a unique urban-modeling solution from Pascal Mueller, who, as a graduate student at ETH Zurich, presented a SIGGRAPH paper in 2006 detailing how he used his technology—the first known scripting language specialized for producing architectural content—to reconstruct Pompeii.

The timing was perfect. It was the spring of 2008, and Mueller was setting up his company, Procedural, to sell the CityEngine software (which was officially released this past August at SIGGRAPH 2008).

CityEngine enables users to model entire cities as much as 10 times faster than with previous solutions. It contains a number of procedural modeling tools for generating large-scale urban layouts. At the software's core is unique shape grammar for efficiently creating detailed building models; the grammar supports a rules-based production scheme of architectural content at arbitrary levels of detail. As a result, it can produce as many buildings and objects as desired, in any style or mix of styles.

Rather than creating a building by hand, which can take upward of a month, the software automatically reconstructs a model by randomizing the windows, facades, doorways, and so forth (in geometric form) based on preset directives—akin to what Guidi's students did in Rome Reborn 1.0. Moreover, the user can choose the resolution of the final output, which can change depending on the application—whether it's low resolution for the Web or high resolution for an off-line rendering. And, as new archaeological findings occur, the entire model can be updated easily to reflect the discoveries. "We never had that kind of flexibility before with Maya or 3ds Max models," Frischer points out.

While it took a few months to set up the building rules in CityEngine, the Procedural group spent less than two weeks on the actual content—something Mueller estimates would have taken two man-years to complete without CityEngine. Each model is generated from geometry in the asset library, so there are no baked-in textures for the higher-resolution imagery, which aver-



Top shows a glimpse of some Class 2 structures in Rome Reborn 1.0; bottom is the same scene in Rome Reborn 2.0.

ages 10,000 polygons; the lower-resolution imagery, meanwhile, contains approximately 400 polygons with baked-in textures.

After the Rome building designs had been specified in CityEngine, generating and exporting the entire 60 million-polygon city model took less than two hours using PCs equipped with the latest Nvidia Quadro graphics cards. "Thus, Rome actually was built in one day...or at least this portion of its digital counterpart was," Mueller says.

An alpha release of Rome Reborn 2, constructed with the Procedural software, was presented at SIGGRAPH 2008. Due to time restrictions, Mueller was only able to create variations of apartment buildings throughout the model. Currently, Team Rome is editing the information, inserting bakeries, single-family houses, and other structures into the landscape.

The high points in Rome Reborn 2 are indeed those unique structures, including the gladiator training camp and the Colosseum, and in front of that, the 100-foot-tall bronze statue of the sun god. Other points of interest are the Arch of Constantine and the Circus Maximus, the great racetrack of Rome that seated 250,000 to 300,000 spectators.

History Continues

"We have realized the centuries-old dream of reconstructing the greatest and most powerful city of the ancient world. The result is an invaluable resource for education, research, and tourism," says Frischer, who estimates that more than 60 people contributed to the project throughout the years. But Rome Reborn is just the beginning. "Great cultural heritage sites—such as Colonial Williamsburg, Giza, and the Sacred Valley in Peru, to mention a few—are next on our agenda," he adds.

Another of Frischer's goals is to illustrate the entire urban development of Rome from 1000 BC to 550 AD. This would involve the establishment of an interactive, online, peer-reviewed journal for which scholars outside the project could contribute 3D models of buildings spanning the entire 1500-year history of ancient Rome.

The journal, to be called SAVE (Serving and Archiving Virtual Environments), "is something we are developing as the world's first outlet for digital archaeologists, to which they can publish their real-time digital models in 3D, along with related documentation and monographs," Frischer says. "That's something that's never been done. Before, scholars could only publish 2D views of their models in print, often in black and white." Before this can be done, however, a commercial partner is needed. Frischer hopes to find one soon and initiate the journal in 2009 or early 2010.

This type of journal needs to support many simultaneous log-ins in a secure format that doesn't allow downloads. Key to this is the RealityServer from Mental Images (owned by Nvidia). The team worked closely with Mental Images to achieve secure remote rendering of the model, thereby protecting the intellectual property of the imagery; the model itself remains on the server, with video streaming to the user's PC instead. "Mental Images adapted its RealityServer software to meet this challenge of simultaneously protecting the IP of the model while allowing the end user to have arbitrarily high-res renderings," explains Frischer.

The group also worked closely with Google Earth to tie the model's documentation to real points on earth and to connect the virtual space with the real space. And last month, Google Earth opened the ancient virtual Rome site to its 400 million users, allowing them to explore the city and pull up details concerning nearly 250 of the buildings.

In another application, a production company has licensed Rome Reborn, which remains the property of UCLA, for an immersive 3D edu-tainment experience called "Rewind Rome." The attraction, part of a themed adventure in Rome, introduces visitors to the era though characters and a plot that unfolds within the ancient cityscape. "It is an educational approach presented in an entertaining way," says Frischer about the attraction that opened last month.

Rome Reborn also has been licensed by Past4Ward, an Atlanta-based start-up that is developing an immersive learning platform that will provide middle school and high school teachers with new ways to interest, excite, and educate students through single- and multi-player interactive, 3D environments that include gameplay. According to Past4Ward, it is planning to

make its Rome Reborn license available to computer-game developers.

Building Blocks of the Future

Indeed, everyone knows that the use of cutting-edge CG helped re-create much of the ancient backdrop in the Oscar-winning film *Gladiator*. Now, just a few years later, academics and scholars have re-created a digital, authentic rendition of ancient Rome for both entertainment and educational purposes. "Here, we are using CG to create a new form of scholarly communication; we are not just making pretty Hollywood models," says Frischer, now a professor at the University of Virginia, where for the past few years he has headed up the Institute for Advanced Technologies in the Humanities.

So, after a decades-long journey, Frischer finally is on the verge of conquering the ancient Rome of his dreams. The project's point of departure was Frischer's experience in seeing early exhibitions of 3D graphics applied to cultural heritage in the early 1990s. The results were technologically impressive but always lacking in scholarly credibility. Today, Rome Reborn 2 has revolutionized CG technology and unearthed new approaches for exhibiting historical findings in museums and classrooms, and on the Internet; it also illustrates the impact CG is having on other fields, such as archaeology and the humanities.

"I hope that Rome Reborn will encourage new partnerships between academia and industry, and between subject experts, end users, and technologists. To achieve monumental results, we need large-scale collaborative teams, and through such teams, we can promote CG and humanistic research, and bring the humanities into the era of Big Science."

Karen Moltenbrey is the chief editor of *Computer Graphics World*.

TECHNOLOGISTS' TOOL SET FOR ROME REBORN

3D modeling
MultiGen Creator
Autodesk 3ds Max

Procedural modeling
Side Effects Houdini
Procedural CityEngine

Laser scanning, modeling
InnovMetric Polyworks

Rendering
Autodesk Lightscape
Chaos Group V-Ray

Remote rendering
Mental Images RealityServer

File-format transfer
Okino PolyTrans

Scene building
Open Scene Graph (open source)

Geo-referencing user interface
Google Earth