BEST PRACTICE

An Ancient City Becomes a Smarter City

The convergence of technology and civic ambition resulted in a unique scanning project involving a handful of Pittsburghers and one Italian city in October 2016. Using a combination of digital tools, a 12-person team of architects, engineers, digital technicians, drone pilots, software gurus and politicians helped the ancient city of Volterra in Tuscany, Italy, begin to document its built environment. During the two-week trip, participants managed to capture the details of design and construction that took place thousand years Before Christian Era (BCE) and learned even more about using technology to support the modern built environment.

The International Reality Capture Workshop was a collaboration between the Volterra-Detroit Foundation, Pittsburgh-based Case Technologies, which was the project's primary sponsor, Autodesk and the City of Volterra. The Volterra-Detroit Foundation is a collaboration between the University of Detroit-Mercy School of Architecture and the city of Volterra, where a residential college was established to house about 20 students in a live/study environment.

Architect/Technologist Mark Dietrick has been a board member of the Volterra-Detroit Foundation since 2010 and he helped lead the project to create a digital model of the Etruscan-era Italian city.

Dietrick, who works as director of services at Case Technologies in Carnegie, became involved with Volterra-Detroit at the request of long-time friend Dr. Wladek Fuchs, the president of the foundation. Fuchs and Dietrick studied architecture together through an international exchange program between the University of Detroit-Mercy and Warsaw Polytechnic Institute. Fuchs has long been a student of Volterra, which is the site of the oldest standing Etrucscan arch (and one of only two) on Earth. Volterra is also home to a recently unearthed Roman amphitheater and a Roman theater, which was discovered in the mid-1960s.

Volterra's mayor, Marco Buselli, was a champion of the workshop. It was his hope that the project would allow Volterra to record the architectural and cultural history of this city of 7,000 people, making Volterra a more attractive tourist destination. The city has been continuously inhabited for more than 3,000 years and has both buildings and remains that are at risk from the ravages of time and the earthquakes that shake the region. The collapse of one portion of its Medieval wall in 2014 showed how vulnerable Volterra's ancient structures were and was another impetus for the workshop.

Overriding all of the motives for the project was Volterra's efforts to receive UNESCO's World Heritage site classification. The research and modeling will allow Volterra to document and explain to UNESCO why the World Heritage classification is justified.

> "We want to be able to extend the experience of that city to anyone, anywhere in the world. It is a remarkable place. Some of the most important archaeological sites that exist are [in Volterra], including one of the best-preserved Roman theaters from the first century BCE," explains Dietrick. "Certainly, the city wants to be able to showcase that. For people who may never be able to get a chance to go there, they can experience it in some way. We also want to use the digital experience to entice people to visit in person and experience it first-hand."

It was also hoped that the models could be used to address some of the deterioration that was occurring at many of the ancient structures. By using regular future scanning to monitor the ongoing condition of the structures, Volterrans could intercede before a failure might occur. The models could also be used to aid in the reconstruction or reinforcement of a failing building or artifact.

The workshop was proposed in April 2016 and took an intensive effort to plan all of the logistics. Case Technologies' owner, Touf Hassoun, saw the project as an opportunity to expose the capabilities of the technology to a broad audience and jumped at the chance to sponsor.

"When Mark came to me with the idea, I thought it was a no-brainer," says Hassoun. "I've always wanted us to have an international presence."

"From Case Technologies' perspective, we wanted to test new technology in a very challenging environment, which it certainly was," notes Dietrick.

Planning began in earnest during the spring, with Case lining up strong partners for the software and hardware to do the capture and modeling. They found a champion for the project at Autodesk in Tristan Randall from San Francisco and engaged 3D Robotics for the drones and Faro Technologies for the terrestrial laser scanners. In addition to Dietrick and Hassoun, three individuals from Civil & Environmental Consultants, Inc. – Pittsburghers Rob Sinclair and Rick Celender, as well as Matt Bainbridge from Fairmont, WV – joined the team to travel to Volterra.

The team was able to board at the Volterra-Detroit International Residential College rather inexpensively (and included great team meals and wine, which Hassoun says brought the group together to share experiences and coordinate efforts). The convenient accommodations made it easier for the team to work long days flexibly while enjoying an affordable price. Even with the advance planning and expertise of the team members, there were hiccups.

Just prior to the arrival of the Volterra-Detroit group, Italy changed its laws regarding drones. Having lined up both drone aircraft and pilots as key components of the project, the team discovered at the last minute that it would have to use local drones and pilots for that portion of the photogrammetry capture that would be done within Volterra's city limits. While there were concerns initially about changing plans for such a critical piece of the project at the last minute, Dietrick says Italian partners APRFlyTech were engaged and allayed the concerns with their expertise.

Once in Volterra, the International Reality Capture Workshop team met with Volterra's mayor to identify what portions of the city were important to capture. The Case Technologies/Autodesk team had its own ideas of what it wanted to record, as did Dr. Fuchs and his colleague, Giulia Monday, who is the program director for the foundation in Volterra. A plan of attack was developed and executed at three levels.

First, the team created 3D models of the important historic structures and archeological sites using 3D Robotics' drones equipped with cameras and 3D Robotics' Site Scan software. Faro laser scanners were used to capture the sites as well from ground level. Autodesk ReCap 360 software was used to produce point cloud models of drone imagery using a photogrammetry web service and also was used to register all of the point cloud data into a contiguous model. Finally, the point cloud model was converted into a textured triangulated mesh model that will be combined with geographic information system visuals like topographical surfaces, roads and rivers to create a complete 3D digital model of the city. This model will soon be accessible online for anyone to be able to experience through virtual-reality interaction.

The project team also created detailed 3D building information models (BIM) of several historic buildings by importing the point clouds into Autodesk Revit and modeling BIM objects using the point cloud for reference as if it were a "live survey." Because most the buildings in Volterra are hundreds of years old at least, few are plum or level; and weather and time have made the condition of the materials and connections unique. Roman-era mortar still binds the masonry, while Etruscan structures used no mortar at all. All of these irregularities are recorded accurately in the scans. While this level of detail may not be practical to model in Revit, the underlay scans will supplement the BIM for reference when applicable. Ultimately BIM of important buildings may include additional information for various analytical and operational processes, but getting the structures recorded accurately was a critical first step.

> "The first iteration of the model will be a visualization model. It will just be a dimensionally accurate visual record, which is important because nothing there is straight," notes Dietrick. "That was important to [Volterra] because if they do have to rebuild, they will want to do so faithfully."

Finally, Volterra's artifacts, valuable architectural details and sculptures were captured with high-resolution digital cameras and converted into 3D models using Autodesk ReMake software. The technological tool that made this phase practical was photogrammetry, the process of stitching continuous digital photographs to measure and capture objects. A series of overlapping photos are taken, roughly every ten degrees, from all angles surrounding an object or building, and the resultant calculations tie all of the overlapping elements into a 3D model or map. From a practical perspective, photogrammetry allowed the team members to use cameras or Smartphones to capture the widest range of objects as they were encountered. The photograms could also be combined with fixed terrestrial scans or drone images to create an integrated model with more detail.

"We had pretty much everybody capturing things as they walked through the city," recalls Dietrick. "We told everybody to be on the lookout. If something grabs your attention, capture it."

The resultant models will be used for online historic exhibitions and research, as well as the opportunity to print reproductions of the individual artifacts or components where the technology is available. The latter utility was one that Dietrick found personally useful a couple of months after the workshop concluded.

> "I actually captured on camera a piece of an Etruscan urn that was quite detailed and ornamental and then 3D printed it after I got home. I used it for Christmas presents," he chuckles. "I thought it would be a great present to share some of these items."

Another unintended benefit of the capture workshop involved an architectural mystery that Dr. Fuchs was finally able to solve.

Fuchs has been researching the Roman Theater in Volterra for several years already and had created his own 3D model based on physical measurements, records and even the writings of Vitruvius, the Roman architect and engineer whose theories on beauty and perfect natural proportions were the basis of Roman architecture. The theater in Volterra was laid out with most of its elements at symmetrical angles and distances that followed Vitruvian principals of proportion, but Fuchs was always troubled by several key elements that were at asymmetrical angles or non-uniform distances from other elements. Roman architecture isn't known for such randomness or carelessness. Fuchs rejected the arguments that the anomalies were accidental or site specific but had no other explanation for them, until the International Reality Capture Workshop.

The captured data allowed Fuchs to look at these out-of-order details in three dimensions. After studying them in this new way, he discovered that the anomalies were in fact fitting together in a form of complete, however previously undocumented geometric system. Fuchs is now studying other Roman theaters looking for answers about where, and why, this geometric system was also being used by the ancient architects.

Dietrick sees a modern application for the same depth of analysis and envisions using three-dimensional thinking about buildings to assess their highest value.

> "I think we can probably say the same thing about any kind of retrofit project. When we undertake a retrofit or adaptive reuse project, we probably don't understand that existing building as well as we should," he says. "We're not able to see all the different aspects when we look at as-built drawings or even walk through it. When we can create a rich three-dimensional model quickly and efficiently and study it in different ways, we should be able to study more creative uses for adaptive building stock."

To that end and spurred on by the work performed during the workshop, the University of Detroit-Mercy recently won a grant to research the use of an indoor drone that it plans to use to capture some of the abandoned buildings that unfortunately dot much of the Detroit landscape. By studying the interior architecture in detail using the models, the researchers hope to uncover best uses for buildings that could unlock higher value for the property.

Dietrick hopes that sort of value capture becomes reality, but in the meantime he is enthusiastic about how the advanced technology has become so accessible to virtually anyone. The apps that allow photogrammetry model generation (like Autodesk 123D Catch) or commercial 3D printing (like 3D Hubs) are free downloads. A digital camera or Smartphone puts the application in anyone's hands. Property managers can document a potential failure and create a model that an engineer or architect can investigate ahead of a problem. Existing buildings can be modeled and replicated precisely in the event of a fire or other disaster.

More interesting opportunities can result from the marriage of capture technology to augmented-reality technology. Field personnel armed with tablet PCs working in an already-modeled building can point the device at a wall or floor and "see" what lies behind the finished surface. The City of Las Vegas, for example, now has much of its underground utilities modeled. Workers know with digital certainty what is buried beneath the streets without exploration. That saves time, money and utility outages.

Rebuilding modern buildings – or even historic American structures – won't be as difficult as trying to reproduce materials and construction techniques that no longer exist. It's not hard to see a future where all buildings exist digitally in three dimensions as well as in reality. Perhaps it's fitting that some of civilization's oldest buildings helped prove that futuristic concept.

The experience definitely whetted the appetite of Case Technologies, which is developing a website dedicated to the Volterra experience. Touf Hassoun has invested in adding laser scanning equipment and software and is anxious to engage in more projects like the International Reality Capture Workshop.

> "I'd love to see us do something like this in Egypt, Peru or Greece, where there are ancient cities and artifacts. I want to leverage what we accomplished in Volterra to document other amazing places for the advancement of historical preservation," Hassoun says.

Volterra's medieval walls contain a city that has been continuously populated for 3,000 years.

The digital wireframe image of the Etruscan arch (inset) was created through photogrammetry and fixed multi-point laser scanning. The information produced a three-dimensional image created by the building information model that was photographic in its resolution.