Paul Debevec and the Art of Photogrammetry

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History


Paul Debevec

Like other seemingly "modern discoveries" such as ray-tracing (1960, not 1984) and subdivision surfaces (1978, not 1998), photogrammetry is actually an old idea revived for modern use in a new application: computer graphics. While French inventor Aimé Laussedat generally is credited with the original idea of using the newly invented camera for mapping purposes around 1850, it was not until the early 1900s that practical applications were realized and used. "Aerial photogrammetry," as it was soon to be called, used numerous overlapping images and known reference points to create detailed relief maps of terrain. The capture of these aerial images was handled over the years by kite, balloon and plane, progressing to satellite and space shuttle. This same basic process has been in continuous use for almost 75 years. Indeed, the Institute of Photogrammetry and Remote Sensing in Finland has been teaching photogrammetry as a formal course since 1946, based on work in that country dating back to the turn of the century. By far, the greatest use for "traditional" photogrammetry to date has been in areas other than computer graphics and visual effects, in areas including archeology, geology, surveying and military planning.


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Modern usage


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In modern digital effects usage, as defined by Paul Debevec, photogrammetry is "a method for interactively recovering 3D models and camera positions from photographs."4 The modern digital breakthrough work done by Debevec, part of the Computer Vision Group at the computer science division of UC Berkeley, was the first research that raised interest in photogrammetry as a tool for visual effects. The simplicity of the work should impress those who have worked in visual effects production, either in digital or traditional model-making. These photographs demonstrate an excellent example of the Facade process Debevec developed. These images represent the reconstruction of University High School in Urbana, Ill. It is worth noting that Facade also was used to model the interior of St. Peter's Basilica for Debevec's film "Fiat Lux," shown in the SIGGRAPH 99 Electronic Theater.

Products


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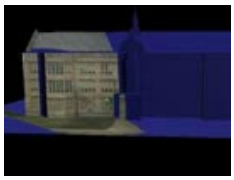
Inspired by the Facade project at Berkeley (Debevec, Taylor and Malik, 1996), **Canoma** is a commercial product originally written by Robert Seidl and Tilman Reinhardt. Sold to Metacreations in 1998 and released as version 1.0 in April 1999, Canoma was acquired by Adobe in August. According to the redirected Web site, "Adobe will announce its future plans for this product line at a later date."

Another popular "image-based modeling" software in production use is ImageModeler from France's **RealViz**. The new V2.0 sports wide flexibility of use and much better texture-management tools. The image of a leaping basketball player below shows the accuracy of an organic subject, as opposed to the more-typical hard surface buildings. ImageModeler is available for both Irix and NT hardware platforms.

PhotoModeler Pro 4.0 is the latest software available from Eos Systems. PhotoModeler Pro 4.0 sells for $795 and runs on Windows 95, 98, 2000 and NT 4.0. With Canoma temporarily out of the picture, PhotoModeler would seem to be the most "mature" software to date for commercial use, certainly the most affordable. The company claims an accuracy of 0.5 inches for a 50-foot object captured at 35mm film resolution.

SynaPix is a relatively new software solution that uses photogrammetry principles for 3D camera path and scene reconstruction from 2D photographs. SynaPix's SynaMatch (formerly MatchMaker) runs on both NT and SGI hardware. SynaMatch is used primarily for "matchmoving" CG elements to live-action background plates. Normally a tedious and imperfect science, SynaMatch greatly simplifies this time-consuming process while creating accurate camera and object information. The company's motto -- "No on-set tracking markers or measurements ...No robotic cameras ... Any shot anywhere" -- is a worthy goal.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SynaPix has SynaFlex in the works for the future of 2D and 3D scene integration. According to SynaPix, SynaFlex is "a revolutionary new system currently undergoing beta testing at leading post-production facilities worldwide (that) offers a brand new approach to 3D visual effects creation while

augmenting traditional post-production. ...SynaFlex will allow artists to manipulate live-action and computer-generated elements as true 3D objects in an interactive layer-free environment." It sounds promising; stay tuned.

Finally, for professional, industrial-strength photogrammetry solutions, there's **Z/I Imaging Corp.**, a joint venture between Intergraph Corp. and Carl Zeiss. Z/I Imaging offers one-stop shopping with everything from multiple software solutions and complete digital photogrammetric workstations to aerial reconnaissance cameras. This level of engineering is typically reserved for government agencies and large corporation. More in-depth information will be available at Z/I's annual camera and digital photogrammetry winter meeting, to be held Feb. 6-8 in Steamboat Springs, Colo.

Photogrammetry in Production

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While many production companies in visual effects have at least experimented with variations of photogrammetry techniques; one in particular, **Pixel Liberation Front**, has extensive experience. "We use PhotoModelerPro for running the photogrammetry solutions and our own custom code to re-project the images onto the 3D geometry," said company founder Colin Green. According to PLF, photogrammetric solutions offer several cost-effective uses, not the least of which is that shooting a well-lit set with wide coverage of still photographs (from diverging angles) will give the director cheap insurance in the form of "synthetic cinematography" months after that set has been struck. Accurate 3D information from such techniques will allow for more than virtual camera moves, of course -- CG creations will have a better tactile connection with the real world and cast more accurate digital shadows on the live-action backgrounds.

In addition to several commercials, PLF has used these techniques successfully on such feature films as "The Cell," "Fight Club" and "Godzilla." For the big lizard running through Manhattan, the CG animators at Centropolis needed a good low-res "matchmoved" set to interact with, the set having long since been sent back to storage and broken down to the original separate buildings. A clever "reverse matchmove" process was used by PLF to photogrammetrically photograph and build each building in order to place it by hand into the animators' scene, to match the filmed live-action footage. This allowed for interactive effects to be placed accurately on building surfaces and the 3D helicopters' flight path to be as close to reality as possible.

The Future

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So what does the future hold? According to Debevec, within a few years, "There will be increasing breakthroughs to close the gap between the fundamentally different 2D and 3D worlds. Active laser sensing used in conjunction with photogrammetric techniques will increase accuracy and eliminate the manual step currently needed to define most photogrammetry-reconstructed surfaces." Debevec imagines the use of such technology to instantly, accurately document the highly complex and irregular surface of a massive archeological dig, for instance, would be possible. No tedious (and fallible) human input is needed to define 3D reference shapes within the recorded imagery.

Breakthroughs could happen at the top-secret **Sandia National Labs** (California and new Mexico), where ultra-high-frequency lasers and CCD arrays work together to record extremely accurate distance information. This "depth camera" technique ideally records z-depth information for every pixel in a captured image frame. One can begin to imagine the possibilities.

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A new Israeli company, **3DV Systems**, recently showed off its ZCAM, which uses an additional infrared signal to captured video footage in order to create real-time depth or "z-axis" info for an object in the live video frame. As the company's Web site says, "The result: Exact 3D location of individual moving objects in the scene. Animation inserted live between moving actors and effects added to objects live without bluescreen are both instantly enabled."

This is all impressive stuff, not only for directors but for people in the production trenches, especially anyone who's done rotoscoping work or wished for a more accurate matchmove. Any technology that eliminates tedium and leaves more room for the purely creative processes should be embraced with open arms.

For further information:

A good brief history of subdivision surfaces.
"A Short History of Photogrammetry" by Robert Burtch of the Institute for Digital Mapping at Ferris State University
Institute of Photogrammetry and Remote Sensing, Helsinki University of Technology, Department of Surveying
Paul E. Debevec
"Fiat Lux": A film by Paul Debevec
International Society for Photogrammetry (ISP)
the Photogrammetric Society
"3D Modeling From Photos: Build 3D Models Fast Using Desktop Photogrammetry" by Lyn Merritt. ISBN 0965947106 (1997)
RealViz ImageModeler Web site

Images and text "Modeling and Rendering Architecture From Photographs" (Facade), by Paul E. Debevec, Ph.D. Thesis, UC Berkeley, 1996. The work was first published in SIGGRAPH 1996 by Paul E. Debevec, Camillo J. Taylor, and Jitendra Malik.

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