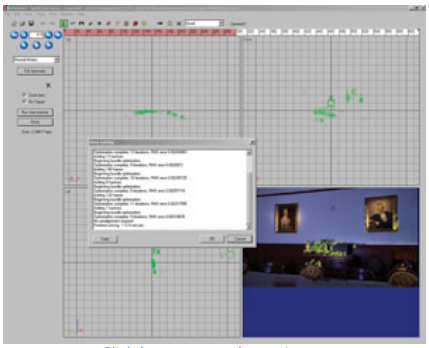
MATCHMOVING DEMYSTIFIED

Make 3D camera tracking work for you and your budget.

By *Mark Christiansen*

The 3D camera tracking process, also known as matchmoving, has become an integral part of effects work in film and video. It's successful when it's invisible—noticeable camera tracking is flawed camera tracking. Realistic compositing of actors into computer-generated backgrounds plays a big role in virtually any blockbuster film you can name, from *King Kong* to *Harry Potter*, to a film with virtually no real sets like *Sin City*. Matchmoving techniques let the director move the camera to a scene that needs computer graphics, and it's not just for nine-figure budgets. Sophisticated 3D tracking software packages—compatible with familiar compositing applications, such as After Effects, Shake, and Fusion, as well as a host of 3D applications—are available at accessible prices for your next project. The process of matchmoving can be mystifying, so I'll break down what it means to create a 3D camera track, identify a few common misconceptions, and offer a brief survey of some of the latest matchmoving software. For more information about what it takes to design and deliver successful matchmoves, see the "Recommended Reading" sidebar.



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Ssontech Syntheyes may not have the prettiest interface, and you'll need to read the manual to make the most of it, but the core features are there for camera solving and the price is hard to beat. There are studios with access to more expensive applications that actually prefer this application. The tracked points are clustered in an arc shape because this shot is a nodal pan; a checkbox is prominently located to specify this important characteristic.

There are many choices in matchmoving software these days, with a variety of capabilities and price tags. Some of the main contenders include 2d3, which is shipping boujou 3 ($10,000) and the more modest boujou bullet ($2,500); RealViz Matchmover ($3,900); Science-D-Visions 3D-Equalizer ($11,990 for the 2K-capable version, $3,590 for the video-res version); Pixel Farm PFTrack ($5,000); and Syntheyes from Ssontech ($399). The prices I listed are approximate because you can add extra-cost options like support, floating licenses, and plug-ins. Although a full-on review of each is beyond this article's scope, I looked at each of them, and did a bit of hands-on with the boujou products, Matchmover Pro, and Syntheyes.

Matchmoving defined

For the purposes of this article, I'll define matchmoving as the use of 2D footage to derive the 3D world in which it originated; and, in particular, the

motion and lens angle of the camera that captured the footage. Each software package previously listed uses the same basic process: It creates a set of 2D tracks mapped to distinct features in the footage, and then uses photogrammetry to calculate the motion of the camera relative to those features—this is known as a *calibration* or *solve* for the camera. The animated camera and associated trackers then can be exported to virtually any soft-ware that works with animated 3D cameras and objects.

The photogrammetry aspect is the most specialized portion of this process, and the reason a whole new genre of software evolved to solve this problem. Photogrammetry is a bit of a dark art that relies on complex mathematical and physical calculations. If you've ever tried to track a 3D camera by hand, you realize that matchmoving software must be accurate below the pixel level. The eye can spot elements that slip even a fraction of a pixel, and most trackers (including simple 2D trackers) are accurate well beyond 1/32 of a pixel.

The process

When you're analyzing a tracking shot, the first thing you must do is ascertain whether you need 3D tracking and whether you have the tools to solve the problem. Some shots with simple camera moves can be tracked in 2D space, and most compositing programs include a built-in 2D tracker. You shouldn't do any more work than is necessary, so you'll want to track only the frames and only the areas of the shot that you need.

If you find that the perspective shifts (due to camera movement) in the area of the shot where you are trying to add an element, 3D matchmoving software combined with 3D animation software may be the key to pulling off the effect. In other words, you need software that can use photogrammetry to calibrate your virtual camera. This process, no matter which application you're using, follows three broad and essential steps. You'll need to (1) derive an accurate 2D track of many features in the scene ("many" in this case can be anywhere from a dozen to several hundred); (2) calibrate the camera, relying on a combination of the software's photogrammetry calculations and any knowledge you have about how the scene was shot; and (3) fit the camera into its target environment, again, using any knowledge you have about the scene.

Because photogrammetry benefits from more 2D tracking points than a simple 2D track, typically you'll have the option of letting the matchmove software automatically choose the tracking points for you. This is certainly preferable to setting several hundred 2D tracking points by hand, but may not fully solve the problem. You'll still need to evaluate the quality of the automatically generated tracks. Taking direct control to delete extraneous points and add points of your own to help steer the track will probably get you closer to the desired result than a purely automated approach.

Calibration of the camera (using photogrammetry) is the "black box" portion of this process; the software is using algorithms that are too complex for you to tweak them. However, you may have knowledge about the scene that can be crucial to getting a good solve. For example, the software can't easily discern the difference between a zoom and a camera move, or between a nodal pan (a camera rotating atop a tripod) and a freely moving camera. If you know whether the camera used a fixed-focus lens or whether it was mounted on a tripod, you can typically improve your results by locking in these settings prior to calibration.

Finally, fitting the camera into the scene can also benefit from knowledge you possess about how it was shot. If you can specify where the ground plane sits in your shot, or if you know the distance between two objects in the scene or between the camera and any object, you'll be able to get a quick and effective fit more easily. This is why it's a huge benefit to have a matchmove artist on the set while footage is being shot. Once you're on the set, you can make your own measurements and take reference photos, or request them from the camera operator. The more you know about each shot, the better off you'll be in post.

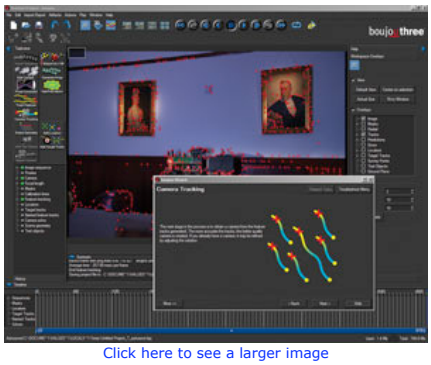
The software

Ten years ago, you could only match a virtual camera to a real one via hand animation. And it's difficult to account for all of the little bumps and weaves that are part of even the smoothest and most regular camera motion.

The software is obviously crucial to this process, and so the question becomes, "Which software is the right choice?" Matchmoving software is hard to compare because there are so many variables involved with each type of shot, and the price differences among the different matchmoving solutions are so wide. Boujou 3 might be more successful at generating an auto track, but if your budget is smaller, you might use Syntheyes because it's a less-sophisticated but workable option requiring little if any extra effort.

All of the software packages I sampled offer a downloadable demo version that

can help you evaluate which one offers the best results on your shots and which user interface you prefer. However, a lot more work is involved on difficult shots than simply choosing the right software, so you may be frustrated after spend-ing several hours refining a solution in the demo version only to realize that you can't save or export it.



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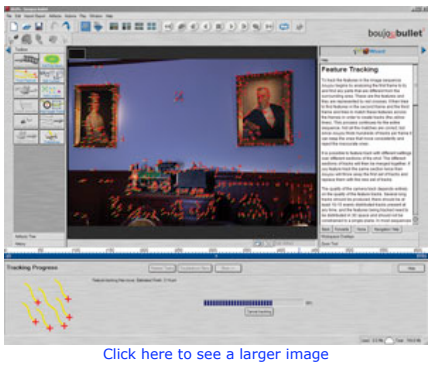
Boujou 3 has a lot of features to help professionals nail a matchmove, and yet the interface still includes a wizard to help walk a user through the process. This higher-end version of boujou is particularly good at solving shots involving a zoom, as is the case on this shot.

In my experience, both flavors of boujou (boujou 3 and boujou bullet) have a strong auto tracker. When I have relatively straightforward tracks, it's often possible to let boujou simply walk me through the process without needing to edit points whatsoever. Boujou bullet in particular has a very clear and informative wizard that not only walks you step-by-step through your tracking process (even in cases where the automatic tracker fails), but also posts the related help content for you to peruse while it does its automated work alongside.



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Boujou bullet can do a thorough job of waking you through the matchmoving process. Not only does the wizard at the bottom of the screen offer you step-by-step options for tracking your shot, but it also offers information from the help database into the UI by default to offer context for your decisions (a first in my experience using computer graphics interfaces).

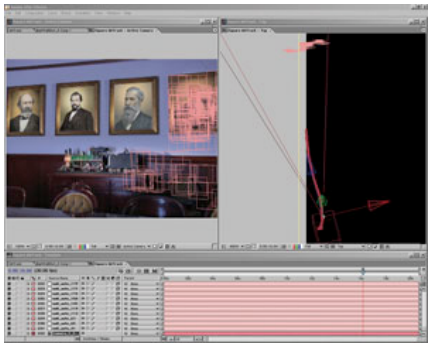
Although boujou 3 and boujou bullet look different, they are similar in many ways: Both have wizard systems and neither has a limit on the image size it will track. Where boujou 3's advantages become clear is solving some of the thorniest tracking problems; in particular, the use of a variable zoom lens. It offers more in the way of tools for analyzing and refining a camera solve.

Matchmover Pro makes it easy to evaluate individual tracking points, so it's less "black box" in its approach than boujou. Syntheyes offers a step-by-step process, although you should read the documentation carefully to get the most out of this toolset.

In addition to these 3D tracking solutions, a new genre of software known as the planar tracker has evolved. A prime example of this is Monet from Imagineer Systems (Reviews, Feb. '06 *DV*). It's not matchmoving software per se because it doesn't produce 3D data whatsoever. Instead, it improves on the hit-and-miss 2D corner-pinning process by using planes and lines in the image, rather than points, to isolate the tracked item—typically something flat, such as a monitor screen. The advantages of this approach are that it tracks and composites as a one-stop solution, requiring no outside 3D program whatsoever. It seems to be accurate (compared with point trackers), so there is less trial and error involved in getting a good track.

Moving forward

In the case of a 3D matchmove, once you have a good 3D calibration, you still need the means to employ it in your shot—and this requires using a second piece of software. This is typically either a compositing package where you'll add 2D planar or (in a few compositing applications such as Fusion 5) 3D mesh objects, or a 3D animation package, in which you can add a full animated, textured, and shaded character.



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In After Effects the Maya scene (consisting of a "baked" camera and dozens of null objects) is matched with the background plate, and the foreground elements (extra pictures on the wall), as well as paint effects (to remove other items on the wall have been placed in 3D space.

You don't need animation skills to complete the process of dropping a simple object into a scene, but it helps to have a thorough understanding of the animation software you use to finish the shot. Taking After Effects as an example, you export the 3D calibration as a Maya .ma scene, which can be imported directly into After Effects. This scene contains a camera and (typically) a large number of nulls corresponding to the points that were tracked in the scene. These points can be valuable for matching the position of real objects because they correspond to the actual corners and details of objects in the scene. It's even possible in some cases to build a simple 3D model using these points as vertices.

In After Effects, of course, it's only possible to incorporate 2D elements into the scene. However, interacting with a full 3D environment opens up new possibilities for selecting, painting, rotoscoping, and isolating elements despite that limitation. For example, in my book *After Effects 6.5 Studio Techniques* (Adobe Press, 2005), I describe, with images, how it was possible to create a full forest inferno with a few dozen 2D flame layers. They are staggered in 3D space in a flyover shot, and because of that, they take on the appearance of full 3D.

Someday soon, 3D tracking software may be an integral part of all major 3D packages. For years it was included in Maya Unlimited as Maya Live, and boujou bullet includes a prominent button to export a camera directly to Shake. Until that time, though, adding matchmoving tools to your arsenal and understanding the process of creating a smooth, believable 3D track can give you a distinct advantage in your effects and motion graphics work.

Recommended Reading

The art of matchmoving is more than just purchasing the software pressing the Go button. That's where books like Tim Dobbert's *Matchmov The Invisible Art of Camera Tracking* (Sybex, 2005) can be a real help. and I worked on several projects at The Orphanage, and he is a vetera such Robert Rodriguez films as *Sin City, Spy Kids 3D,* and *The Adventure Sharkboy* and *Lava Girl in 3D*, all of which used few or no sets, rel instead on 3D matchmoving to place the actors seamlessly into t computer-generated environments.

The book is a well-organized and logical examination of the issues that n be considered to create successful matchmoves. Rather than limiting him to a particular software solution, Tim focuses on the general principles practices of matchmoving, so no matter what 3D camera tracking pack you decide to work with, you can still make use of his expertise.

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software.

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