Advanced projection techniques, Part 2—Image tracking and movement

A projection technique utilizing location tracking of screen elements has been used infrequently in the past, but is now picking up speed.

Picture a large object on a stage, perhaps a box or wall with a window. Now, imagine that the box is being used as a screen surface for a projected image, as is the window in the wall. Finally, imagine that the object moves from center stage to stage left and that the image moves with it, as if it painted on the object. That, in essence, is the advanced projection technique of image tracking.

The basic technical concept involves creating a projection space (raster area) larger than the scenic object, creating a window within the raster (Picture-in-Picture or PiP) that matches the scenic object and then moving the scenic object in the physical world, while the PiP moves synchronously in the electronic world. Figure 1 illustrates the basic concept.

This technique was first used (to the best of my knowledge) for a show we worked on called *Sinatra, The Man, His Music*, which ran at Radio City Music Hall back in 2006. At that time, the image-tracking concept was significantly challenged by two factors; a lack of a predictable rate of movement for the large scenic pieces being used, as well as the very complicated electronics required to create the PIP windows and move them in a synchronous x/y pattern.

We were eventually able to make it work, and when it did it looked fabulous, but it didn’t take long for advances in automation controllers and media servers to make the task much more reliable and simpler to perform. In fact, so much so that only a year later a version of this production in London was accomplished with relative ease and a much smaller complement of gear. Currently, with a few notable productions making extensive use of image tracking, including the current Met Opera *Ring Cycle*, the technique is having much greater impact in the theatrical production world.

What makes this technique so interesting is that it requires a comprehensive bridge between two very separate disciplines—scenic fabrication and projection design—so that the image generating system can locate the scenery in the projection environment and track movement. Our exploration of this technique will begin with this crucial element.

Tracking methods

The type of movement most common in a tracking system will be along vertical and horizontal axis that correspond with x, y coordinates, see Figure 2. More complex systems will incorporate the z, or upstage...
downstage axis along with rotation of the scenic objects within the x, y, z coordinates. Note that the limitation here is not in the image processing electronics but in the stage design and corresponding scenic automation system, which may limit the range and form of movement.

As stated earlier, the object to be tracked can be flat or dimensional, although the dimensional objects will pose a greater challenge for the image processing system than a flat surface. For clarity purposes, the following process is based on using a single flat plane as the tracked projection surface.

With a selected point on the scenic object designated as the image origin point (e.g. the lower stage right corner of our box) and the window in the projected raster sized correctly to match the size of the surface, the projection system is ready to receive positioning data from the moving scenery. This can happen in a couple of different ways as described in the following sections.

### Tracking with automation data

Assuming the moving scenic object is not being pulled by a stagehand with a block and tackle, but is being actuated by a computer controlled winch system, it’s likely that the computer system has an idea of where this object is in the x, y landscape. If that’s the case, it may be possible to extract that location information and create a data stream that the image processing system can interpret.

While seemingly convenient, this method presents some pitfalls. One is a timing issue that can occur if the automation system outputs data that translates as “I just moved the object from 100, 150 to 200, 250,” versus “I am moving the object from 100, 150 to 200, 250.” In the case of the former statement, the image processing system is receiving old information for an action that has already taken place. This means that the image window will follow the object but will lag behind, which will be very noticeable.

If the automation data stream is accurate and timely, however, it may be possible to utilize the information for tracking purposes.

### Tracking with external data

Another method used to track scenery is to add devices to the objects that will provide exactly the kind of location data the image processing system requires. If the scenery and the design allows for the addition of the devices, this is an excellent option as the device can be tailored or programmed for the specific object and movement.

One tried and true method is to place a shaft encoding system on the mechanism or motor that is moving the object, see Figure 3. The small, patterned wheel is read by a sensor and calibrated for the speed and length of travel. The resulting data, which is output instantaneously, provides accurate and timely location information for image processing system. A similar system utilizing a marked tape strip, which is applied to the tracking surface along the path of travel, can also work but is not quite as reliable as the shaft encoding method.

There are other more exotic methods, including laser-based distance measuring devices, which can be adapted for data output. These devices have the advantage of being single components rather than a reader/marker pair and we have used them for some unusual applications, including a project that required tracking the movement of a building elevator.

### Tracking with video image data

Another method for tracking movement, which does not require mounting equipment on the scenic object, is supported by using video image data derived from a video camera trained on the scenic object. Specialized image recognition software, typically developed for the specific application, is used to interpret the video image, recognize the object being tracked,
and correlate the movement of the object within the fixed environment.

This type of object tracking can be very flexible, albeit often less precise. It works well for irregular shapes; human shapes for example, and can be seen at work in some innovative dance performances and at the Met Opera Ring cycle productions.

The imaging system’s ability to sense or “see” the objects can be affected by numerous factors, including lighting, patterned backgrounds, or complex movements and that can lead to inconsistency in the tracking data. To mitigate this, it is possible to add emitters to the objects to create signatures for the imaging system. For example, infrared LED’s can be installed in the set to mark object boundaries, which are easily discerned by the tracking system.

Combining tracking methods
In highly complex systems, with many objects, and different types of shapes to track, an effective approach will utilize as many tracking methods as necessary to provide accurate tracking data to the imaging system.

The modern image processing system for tracking
The power and flexibility of the modern media server makes it the ideal platform for tracking systems. The servers provide a conduit that allows the programmer to link image layers with external data and because servers support multiple layers, it is possible to create multiple image scenarios linked to various types of tracked data.

While the specific method varies from server platform to server platform, in general, the programmer will configure the system and timeline so that a given set of external data will trigger cues that affect the image layer. A typical example would see a response to external data result in the playing of a video clip sized to match to a scenic object followed by the movement of that sized video clip from one section of the pixel space to another, in sync with the scenic object.

It is important to note that process of image tracking results in a loss of image resolution. This is due to the fact that the image tracking methods described here use the projector to create a large image area and then only use a portion of that image area at any one time—the image is being specific to where the scenic object is located. In practice, this might decrease active image resolution to a small fraction of the overall image resolution, as shown in Figure 4.

Therefore, care must be taken to avoid scenarios where active image resolution is so low that individual pixel elements are visible to the audience—a calculation based on pixel size and audience viewing distance.

Image tracking using moving projectors
In all of the prior examples, the approach to image tracking is based on using one or more static projectors in fixed locations. Another approach for image tracking involves the use of projectors that move physically, in synchronicity with the movement of the tracked object, similar to how a moving light would be programmed.

In the case of the moving projector, it is a little more complex than utilizing a moving light because the projected image must be processed to the correct size and shape on a continuous basis as the projection surface moves in the physical environment. Without this correction, the image would change shape and size depending on the spatial relationship between projector and image surface.

The moving head projector systems do this job very well and they can provide a straightforward alternative to the somewhat more complex systems described above. In addition, since the raster is sized to the object, rather than the object moving within a much larger raster, light output is preserved and resolution is maximized.

The downside of the moving projector is that often the system must be programmed so that its movement mimics the physical objects movement and this is typically accomplished in a manual fashion via light board programming. This is in contrast to the more automatic methods described above, where movement data triggers the system. While both approaches require a reasonable block of time on site to align the system, it is likely that the moving projector, manual approach will take longer and be less repeatable.

Figure 4 – illustration depicting the difference between raster resolution and active image pixels
Creative uses for image tracking

Having established the methods for moving a projected image in sync with moving physical objects, it would be worthwhile to examine the reasons why anyone would want to do it in the first place.

In theatrical applications there is a clear and compelling reason to explore image tracking when projection is part of the scenic design. For example, if the script calls for display of an image clip and that clip will play on a scenic piece, a wall for example, what happens if the wall tracks on-stage during or prior to the cue? Will we be satisfied with a set of cues that involves the wall moving into position, coming to rest, the video playing, the video ending and the wall moving back off-stage? Perhaps, but it may be much more dynamic for the video treatment to begin as the wall tracks on stage, creating a reveal of the video that can build as the wall reaches its stop point. That is one of the simplest and most effective uses of image tracking.

Other creative possibilities include imagery that changes or follows the movement of actors, creating an interactive presence. Or, by creating content that changes perspective in sync with physical movement, the designer can create wildly exaggerated forced perspective effects that seemingly alter the size of the physical space itself.

Content design and image tracking

The final area of this topic to be explored is the design of the actual video content used in image tracking scenarios. Similar to content requirements for other advanced projection techniques, there is an obligation to design content that effectively supports the technique.

The design of the content must take into account that the surfaces displaying the content are moving and that there is a narrative reason for this to take place.

"The design of the content must take into account that the surfaces displaying the content are moving... and that there is a narrative reason for this to take place."

The design of the content must take into account that the surfaces displaying the content are moving that they are moving at a particular rate of travel and that there is a narrative reason for this to take place. Otherwise, the result appears to be a movie screen that happens to be moving around in space for no particular reason and that may not escape the notice of the viewer.

Josh Weisberg is President of Scharff Weisberg, Inc., an audio, video, lighting, and staging and rental company located in the New York metro area. To learn more about Scharff Weisberg, Inc., visit www.scharffweisberg.com.