Digital Air - Techniques

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Space-time notation system designed by Mark J. P. Wolf
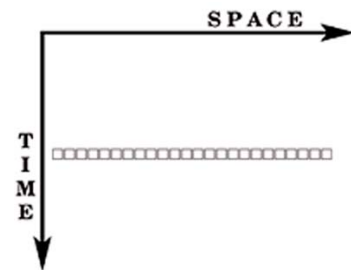
frozen moment

WENDIGO (2001) - dir. Larry Fessenden - Timetrack™ 80 lens camera system

To record a frozen moment we trigger all of the cameras in our systems simultaneously. This results in a number of images of the subject from a number of different points of view - all taken at the exact same moment in time. These individual images are then transferred sequentially into a computer and stabilized to make a smooth motion picture of a moment frozen in time.

That's not all that our systems can do, however. The frozen moment is just one dramatic example of the power of Digital Air's camera systems over the relationships between space, time and camera movement in motion pictures.

The other visual effects discussed in these pages illustrate a variety of additional sometimes subtle, oftentimes dramatic, ways in which Digital Air's camera systems can be used to defy our most basic assumptions about space, time and camera movement in motion pictures.

> frozen moment

In the above example of the frozen moment effect all 80 of the Timetrack™ camera's shutters opened and closed simultaneously.
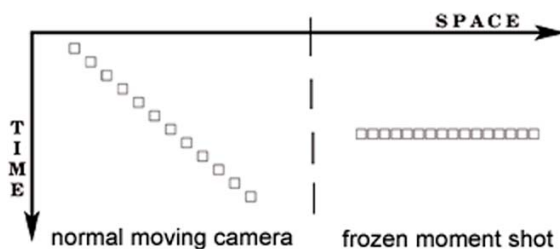
In the space-time notation above downward movement on the time axis indicates the passage of time, while movement on the horizontal axis indicates a camera movement through space. It is important to note that the space axis represents the speed of camera movement and the relative distances moved, but it is generalized camera movement, and not movement in any specific spatial direction.

(from Space Time Frame Cinema by Mark J. P. Wolf)

Timetrack™ 80 lens curved camera in London

live action

Castrol GTX live action TV commercial - dir. Ronaldo Soares - Timetrack™ 36 camera digital HD-1 system

To shoot live action we trigger our camera systems sequentially rather than simultaneously. This introduces a time-offset from camera-to-camera. For example, to shoot at 24 fps we introduce a time offset of 1/24th of a second.

While it is generally easier to shoot live action with a motion picture camera there are several reasons that we might want to use Digital Air's camera systems instead.

One reason is slow motion. Because the time offset between each point-of-view in our systems can be very small we can use live action (i.e.: sequential triggering) to shoot super slow motion - achieving frame rates all the way up to an infinite number of frames per second (the frozen moment).

The live action technique can also be used for shooting matching plates. By shooting multiple plates within the same camera system (for example a frozen moment and a live action plate) we can composite them together in post production just as easily as if they were shot with motion control. This lets us easily introduce moving subjects into the frozen moment.

Shooting live action within our systems also allows us to create seamless transitions from live action to the frozen moment.

The live action technique can also be used as an alternative to motion control in situations where it is easier to use our systems than motion control, for example on a moving car.

Our camera systems can also be used to produce super-fast fully repeatable camera moves with completely independent control over camera movement and frame rate.
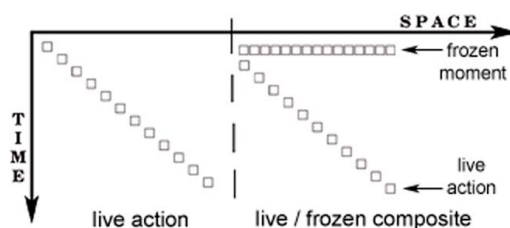
> live action
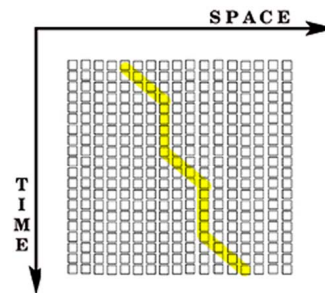
This example of live action was recorded by streaming uncompressed frames from every camera in our Timetrack™ digital system directly to disk. Because every camera was constantly recording the exact timing of the virtual camera movement (indicated by the yellow frames in the graphic above) could be decided entirely in post.

Timetrack™ HD-1 digital system in Rio de Janeiro

stop start

AES Electropaulo TV commercial - dir. Julio Xavier – Timetrack™ 80 lens camera system

Time stop-start is the moment of transition from live action to a frozen moment.

There are several ways this transition can take place:

The live action shots can be shot with a cinema camera or they can be shot within Digital Air's camera system using our live action shooting technique.

If we shoot the live action shots with a cinema camera the cinema camera can be stationary or it can be moving.

If the cinema camera is moving at the same rate and in the same direction as the virtual perspective of Digital Air's camera system the overall camera movement will appear continuous through the transition.

Time stop-start can also be introduced with a time ramp or a space ramp - so that time or the camera movement or both may appear to slow down (or speed up) before time stops.
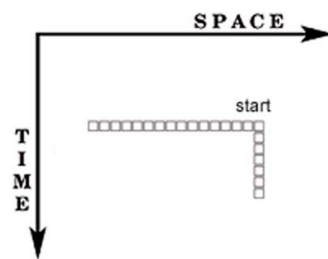
For this example of the stop start effect we mounted an Arri 435 on the end of a Timetrack™ 80 lens curved camera and cut to the Arri after the Timetrack™ shot.

> stop start
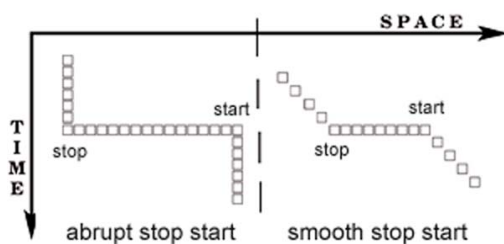
Timetrack™ 80 lens camera in Sao Paulo. Brazil

slow motion

2004 Athens Olympics opening graphics - dir. Daryl Goodrich - Timetrack™ 36 camera digital HD-1 system

Slow motion, like live action, is achieved by internally triggering Digital Air's camera systems sequentially rather than simultaneously.

Because the rate of triggering can be very high all the way up to simultaneous our camera systems can easily record events in super slow motion. For example, using our digital systems we can shoot at any frame rate up to 24,500 frames per second camera-to-camera.

Unlike a motion picture camera the rate of the sequential triggering in our systems can exceed the shutter speed of the camera. This means there is no theoretical limit on how high the frame rate can go (in fact the frame rate can go to infinity - or simultaneity - as it does in the frozen moment).

When using a single high speed camera to shoot slow motion, changes in the frame rate of the camera effect both the motion of the subject and the motion of the camera. With our systems the effect of the high frame rate (across the system) on the speed of the subject is completely independent from the speed of the camera movement. This is because the camera movement is virtual and the speed of the virtual camera movement is dependent only upon the spacing of the cameras.

> slow motion
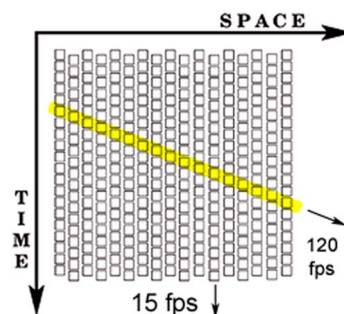
The above example of our slow motion effect was recorded by streaming uncompressed frames from every camera in our Timetrack™ digital system directly to disk with a time offset. Each camera recorded at just 15 fps, but because of the time offset the effective frame rate when cutting across the image sequence is 120 fps.

Timetrack™ 36 camera HD-1 digital system in London

time ramp

Carte Aura - Italian TV commercial - dir. Paolo Gandola - Timetrack™ 80 lens camera system

A time ramp occurs when there is a frame rate change within a shot. For example when the frame rate changes from 24 fps (normal time) to 250 fps (slow motion).

In Digital Air's camera systems the frame rate is free to change gradually or abruptly. This is because changing the frame rate is simply a matter of changing the timing of the internal triggering of the cameras across the system.

Because the frame rate in our systems is free from any mechanical or inertial constraints and the virtual point of view of our systems can be in two or more physical locations at the same time, we can, for example, slow down and stop time then reverse it and make it go backwards - all within a single continuous shot from a moving point of view.
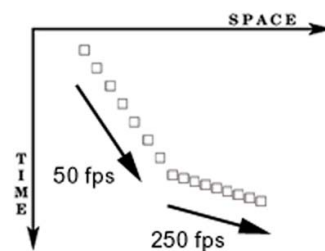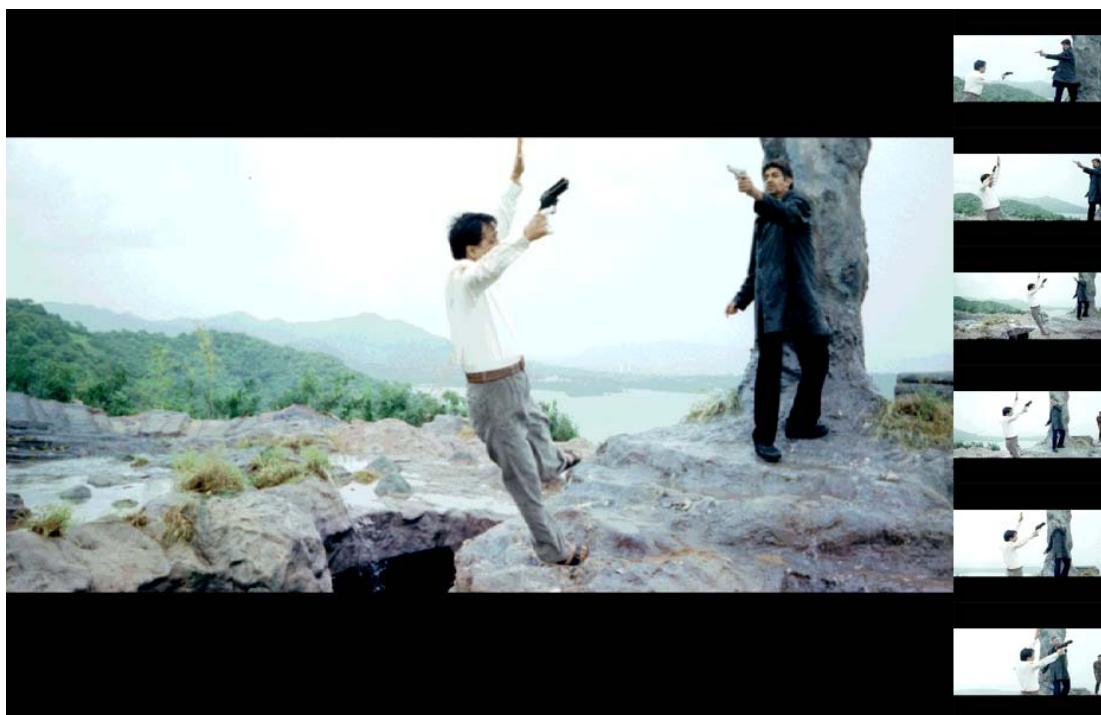
> time ramp

This example of a time ramp was recorded by mounting an Arri 435 on one end of a Timetrack™ 80 lens curved camera and moving the entire system (Timetrack™ and Arri) on a dolly during the take (see photo below). The Arri's frame rate was 50 fps and the Timetrack™ camera's frame rate was 250 fps (sequential).

time slows down - stops - and reverses

Timetrack™ 80 lens curved camera in Milan

space ramp

AKS (2001) - Indian feature film - dir. Rakesh Mehra - Timetrack™ 160 lens camera system

A space ramp occurs when the speed (through space) of the virtual moving camera changes within a shot. For example when the speed changes from ten meters per second (a relatively high speed) to one meter per second (a much lower speed).

To achieve a space ramp within our systems we vary the distance between the cameras gradually (or abruptly) across the system - either physically in the rigging or by dropping frames or interpolating frames in post.

The concept behind the space ramp can be applied to any camera movement path, so for example, within a shot the virtual camera can very abruptly (instantaneously if desired) change direction and or speed without impacting the frame rate. With a normal cinema camera issues of physics and inertia tend to constrain camera movement when physically moving a camera, making abrupt changes in velocity all but impossible.
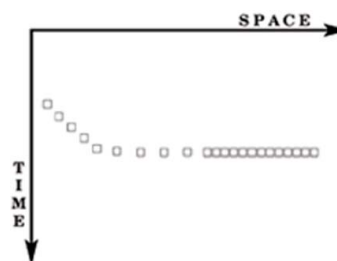
This example of a space ramp was recorded by mounting an Arri 435 (for the live action) on one end of a Timetrack™ 160 lens camera and operating the Timetrack™ camera in frozen moment mode (simultaneous shutters). In this shot the ramp is a sudden change and was created in post by dropping frames in the first half of the shot, which in effect creates more space between each Timetrack™ frame and speeds up the virtual camera movement in the first half of the shot.

> space ramp
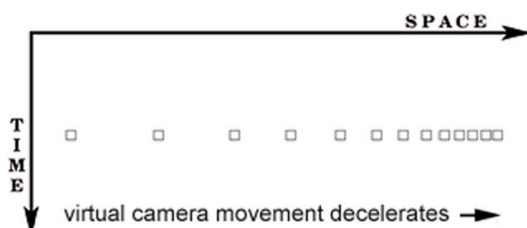
Timetrack™ 160 lens camera on location in India

time blur

Time blur test 2004 - Timetrack ™32 camera digital HD-1 system

Time blur is motion blur which results purely from the movement of the subject over time. Time blur usually requires relatively long exposures but it can also be created from multiple frames through interpolation.

The shutter speeds of the cameras in Digital Air's systems can be much longer than the frame rate. As a result time blur can be introduced to a shot even at very high frame rates (in cinema cameras higher frame rates necessitate shorter shutter speeds). Additionally, time blur in our systems can be time-progressive.

It's important to note that the virtual point-of-view of our systems can "move" relative to a time-blurred subject without the time blur effecting the background (or any static objects in the scene). This is because Digital Air's systems simulate a virtual moving point of view by cutting across static camera positions - and non-moving objects in static shots are unaffected by time blur.

By simultaneously opening and then sequentially closing the shutters in our systems we can also record scenes in which the subject is moving and leaving an accumulative trail of time blur (this is similar to the light painting effect only the subject itself becomes the light source). Because this creates a situation where each frame has a different shutter speed an exposure compensation may be made in the aperture settings or with ND filters, or the effect can be recorded with a moving subject on a black background.
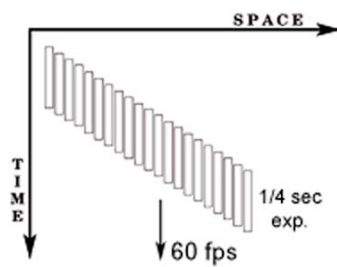
The above example of time blur was recorded with 32 Timetrack™ digital cameras running synchronously and out of phase by 1/60th of a second. The cameras were arranged and triggered in a circle such that the triggering cycle revolved constantly around the circle making one complete revolution approximately every half second. Each camera's shutter speed was 1/4 sec. The result is extreme time blur that looks like the cameras were running at only 4 fps while the subject actually moves in slow motion because the frame rate of the final shot is 60 fps.
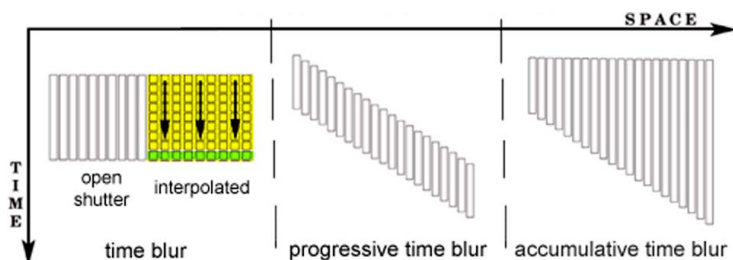
> time blur

space blur

"Time of Your Life" TV show promo - dir. Bryan Johnson - Timetrack™ 80 lens camera system

Space blur is similar to time blur but on the spatial axis. Space blur looks like motion blur resulting from movement of the camera.

With a single still camera space blur can be captured by moving the camera during the exposure. But with Digital Air's systems the individual cameras within the system are not necessarily moving, moreover, if the subject is a frozen moment there is usually no time to move the cameras. As a result space blur generally requires the use of interpolation.

Because any number of frames (camera positions) can be interpolated to create space blur the effect can range anywhere from barely noticeable to infinitely extreme. As a result shots can blur in and out to such a degree that their subjects completely disappear and reappear.

Objects placed at the nodal point of a curved camera system will tend to remain relatively sharp even when extreme space blur is applied. You can see this in the image of Jennifer Love Hewitt above. This was shot with our 80 lens curved Timetrack™ camera and all 80 frames were interpolated to make this one image. This contrast between blurred background and sharp subject can be amplified by compositing a sharp base-line raw image sequence of the subject (the green frames in the graphic to the right) over a space-blurred background plate (the yellow frames interpolated together across space).

> space blur
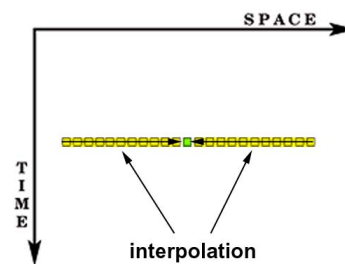
In this example of space blur multiple frames from a standard frozen moment shot were interpolated together across space to create one frame with space blur.

space blur - concept   space blur - interpolated   space blur - diminishing
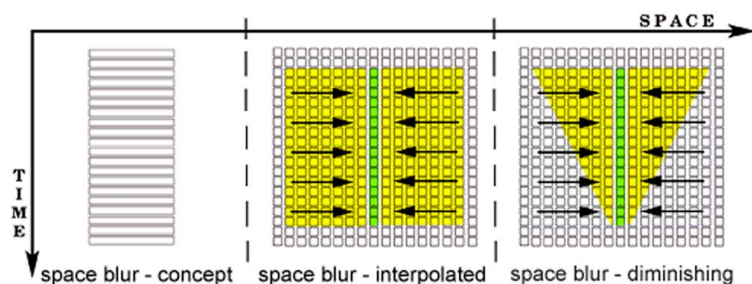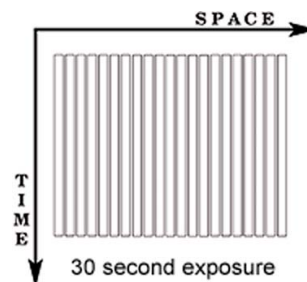
long exposure

Samsung TV commercial out-take - dir. Chee-Whan Chung - Timetrack™ 40 lens camera system

Night photography requires long exposures, photo strobes, or cinema lights. In still photography the solution is usually a combination of the first two, while in cinema it's almost always the latter.

The larger the subject or more distant the landscape is the more difficult and expensive it is to light it with cinema lights. When still photography techniques are used, as is possible with Digital Air's systems, the solution can be much simpler. Long exposures can be used to capture night landscapes and other under-lit or otherwise unlightable scenes from a moving point of view. High powered strobes such as Lightning Strikes can be used to illuminate city-scapes and landscapes momentarily with the effect of looking like constant light sources in the final shot (imagine a strobe-lit cityscape as a frozen moment).

Long exposure techniques are useful in their simplest forms for capturing background plates of distant night exteriors. In more complex forms these techniques blend into the open flash and flash trail techniques.

Very long exposures (several minutes or more) can also be used to photograph scenes in which everything moving disappears due to motion blur. This technique has been used in still photography for example to make a busy train station appear empty.

30 second exposure

This example of a long exposure is an outtake of the crew standing around after this shoot was over. We chose to include it here because it's a night cityscape shot with a long exposure and only ambient light -- streetlights, etc. (as opposed to using cinema or strobe lights).

> long exposure
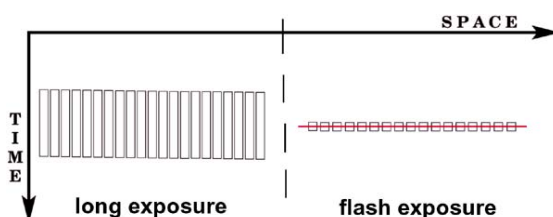

long exposure   flash exposure

Photo: O Winston Link
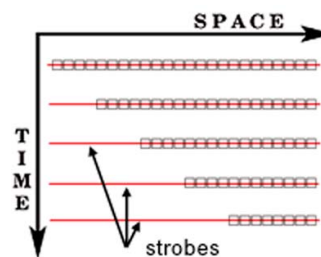
multiple exposure

BMW 3 Series TV commercial - dir. Michel Gondry - Timetrack™ 160 lens camera system

Multiple exposures are relatively simple to achieve in both still photography and cinema - one simply exposes the film multiple times. To record multiple exposures with Digital Air's camera systems each individual camera's shutter opens two or more times during a single take and as a result two or more images of the subject appear in the same shot with a time offset.

This technique can be combined with a sequential shutter effect so that, for example, a person can walk through a shot with an identical synchronous double following just behind. These doubles may also accumulate or disappear over time.

Any number of multiple exposures can be achieved - literally thousands if desired.

The multiple exposure technique can be captured in camera by opening and closing our system's shutters, by leaving the shutters open and using strobes, or by a combination of both shutter and strobe timing. Multiple exposures can also be created in post by adding multiple frames together.

This example illustrates how multiple exposures can progressively accumulate or disappear over time by lighting a scene with multiple strobe pops and progressively closing or opening the shutters across a Timetrack™ camera system. In this example the strobes were controlled by our 160 lens Timtrack™ camera and even the headlights on the moving car were strobes.
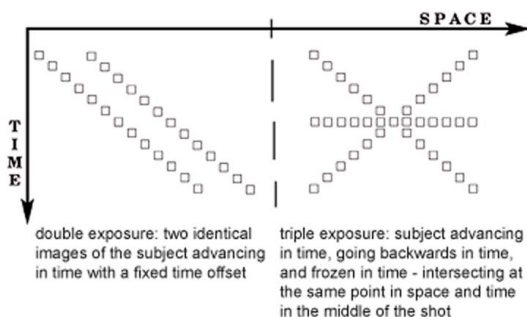
 > multiple exposure

double exposure: two identical images of the subject advancing in time with a fixed time offset

triple exposure: subject advancing in time, going backwards in time, and frozen in time - intersecting at the same point in space and time in the middle of the shot


Photo: Andrew Davidhazy

open flash

Orange Photo Messaging TV commercial - dir. Chris Cunningham - Timetrack™ 160 lens camera system

Flash photography freezes the action. Long exposures result in motion blur. The combination of the two is called open flash. Open flash can result in fascinating mixtures of photographic clarity and motion blur.

With Digital Air's camera systems we can use the open flash technique in ways that are impossible with a motion picture camera or a still camera. For example, we can off-set long exposures across the system (see chart below) so that there is movement in the motion blur effect.
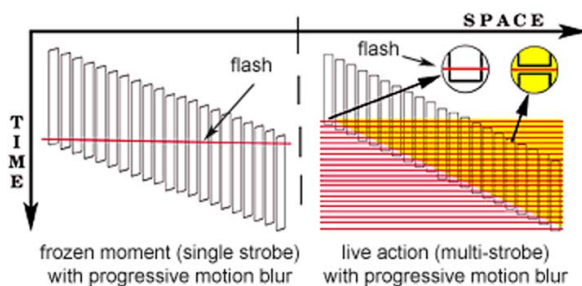
We can also produce live action images of the subject that move forward in time normally by illuminating the subject with high speed sequential strobes.

Controlling when the photo-strobe(s) fire relative to the long exposure gives the director control over whether the blur is in front of or trails behind the flash exposure.
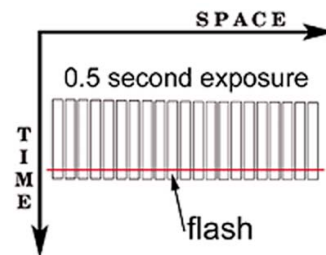
> open flash

This example of open flash is a long exposure with a single flash at the end of the exposure. The flash was produced with a Nikon Speedlight (a small still camera flash) and was triggered by hand just before the Timetrack™ camera system's shutters closed.

frozen moment (single strobe) with progressive motion blur   live action (multi-strobe) with progressive motion blur

Timetrack™ 160 lens camera in London

flash trail

Lux TV commercial - dir. Vaughn Arnell - Timetrack™ 80 lens camera system

In this hybrid live action / multiple exposure technique a sequence of frozen images of the subject are progressively left behind as the subject moves naturally through time and space while the virtual camera moves around the subject. The virtual camera movement reveals the three dimensionality of the frozen images.

This technique is achieved by lighting the scene entirely with high speed photo strobes and controlling the relative timing of Digital Air's camera system's shutters and the strobes.

Because of the high number of multiple exposures this technique is best achieved with a moving subject on a black background (to avoid saturation of the subject and / or the background). If a non-black background is desired in the final shot the effect can be composited with a different background plate.

To light the shot pictured above we used forty Broncolor strobe packs synchronized to our 80 lens Timetrack™ camera systems. The Timetrack™ cameras produced 80 timing events per second across 40 lighting channels with two separate exposure events per frame-cycle and as many as 80 exposures per frame over two seconds (two seconds being the time it took to record one 80 frame shot at 40 fps).

> flash trail
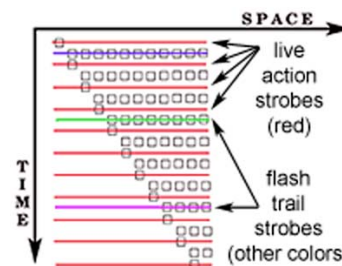
This example of the flash trail effect was shot in a studio on a black background. The leading "live" image of the actress was illuminated frame-by-frame by strobes that flashed as one Timetrack™ shutter at a time opened sequentially across the camera system at 40 fps. The irregular trail images were illuminated by another set of strobes that were timed to go off when multiple shutters on the Timetrack™ camera were opened between those individual shutter events. The softer more regular underexposed images were created by ambient light that was "always on".
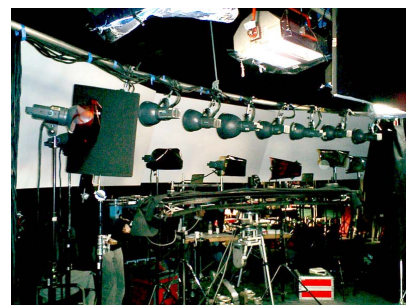
Timetrack™ 80 lens camera with strobes in Miami

light painting

Nissan "Liquid Light" TV commercial - dir. Rupert Sanders - Timetrack™ 80 lens camera system

Painting with light is a technique in which very long exposures record the movement of sources of light over time. Using Digital Air's camera systems this technique can be made time-progressive, i.e.: the paths of the light sources can be moving in both space and time in the final shot. The result is a three dimensional image of light being painted in time.

The actual painting can begin after our camera system's shutters open but before the time progressive portion of the exposure event begins, so, for example, a complex drawing can be made over several minutes and we only see the last few seconds of the motion in the final shot (although we see the entire light painting). Or the time-progressive frame rate can be slowed down during the shooting, so that something that takes several minutes to paint may appear to paint itself in just a few seconds when played back.

The light painting technique can be combined with live action in camera by using timed photo strobes as in the flash trail technique, or in post through compositing. Multiple plates can be used to place light painting in front of and behind live action and the live action technique can be combined with other techniques to bring additional artistic possibilities to the live action plate.

A light painting on white effect can be achieved by shooting inverse colors on black. The image to the right below was shot as red light on black.

> light painting

still from Orange Photo Messaging shoot 2002
(negative print) - 160 lens camera
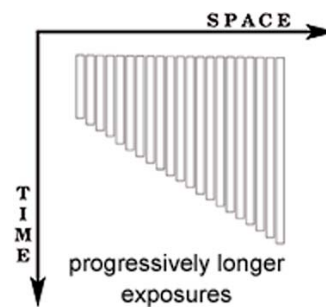
This example of light painting was shot in a studio on a black background. The Timetrack™ cameras' shutters opened simultaneously and then progressively closed over two to four seconds as the light sources (fluorescent tubes) were moved through space by the director and the gaffer -- who were dressed head-to-toe in black. The distant studio wall that you see in the background in some shots was a separate plate. A separate plate of the car lit with a Fisher light was also shot for each setup and in some of the shots this plate was mixed in with the light painting plate.

motion distortion

Motion distortion test 2004 - Timetrack™ 32 camera digital HD system

Motion distortion occurs when an image is progressively scanned by a camera at a slow scanning speed. With a film camera this can be done by using a slit shutter near the film plane. With a digital camera this can be done using a slow rolling shutter or slow progressive-scan imager.

When the subject moves during a slit-scan exposure parts of it will appear lengthened, shortened, or inverted depending upon the speed of its movement relative to the speed of the slit or scan line. This "property" of the effect can be exploited in predictable ways, as in the photo below right, or in unpredictable or random ways.

Using a slit-scan or progressive-scan camera, when the camera moves the background becomes distorted as well. But using Digital Air's camera systems, which don't actually move, the background and static objects in the scene appear perfectly normal. Only moving subjects, such as people in the shot, appear distorted. Of course if the camera array is moved during the exposure both will appear distorted (albeit differently).

This effect can also be time-progressive.
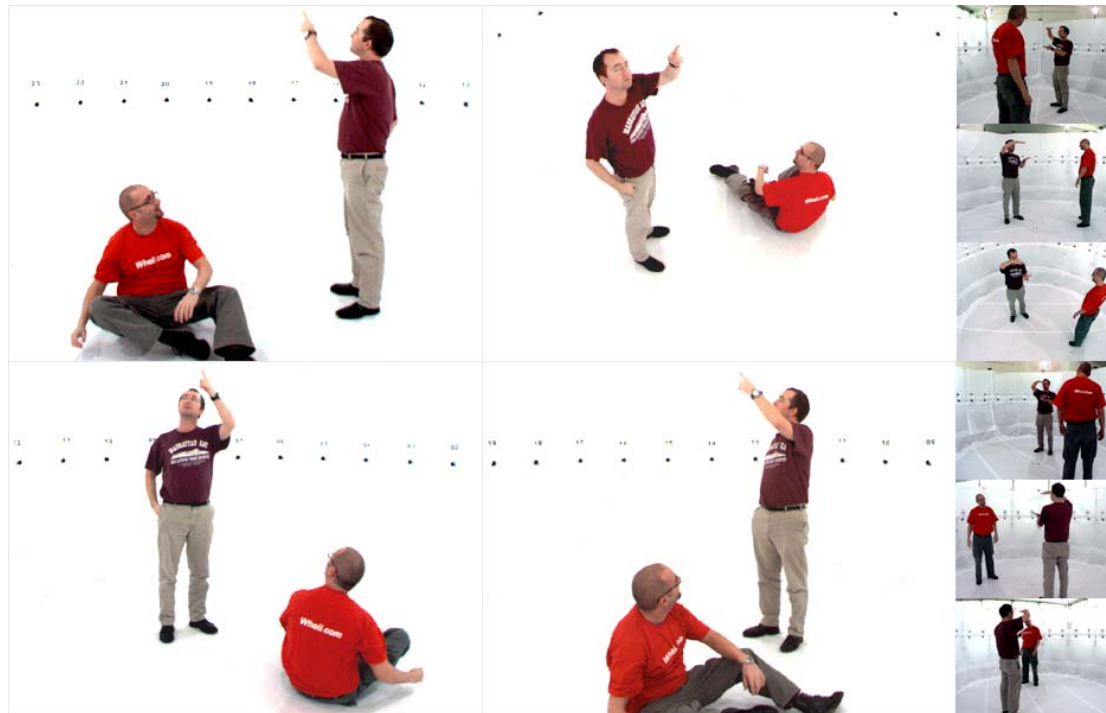
> motion distortion
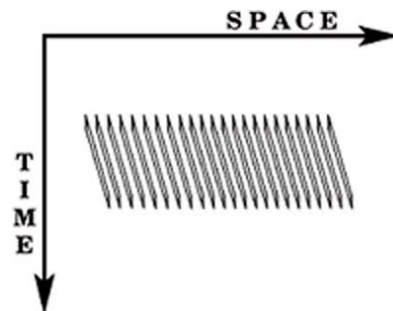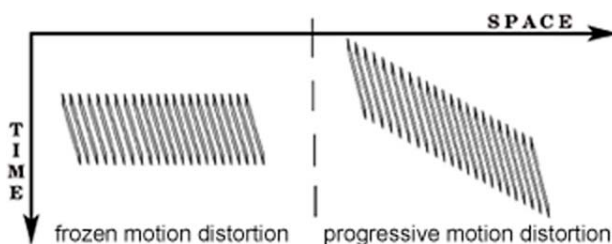
This example of motion distortion was recorded with 32 Timetrack™ digital cameras recording full frame uncompressed HD images synchronously at 30 fps. The slit scan shutter effect was then interpolated over several seconds of recording time.

frozen motion distortion   progressive motion distortion

photo: Andrew Davidhazy

match cut

Match cut test 2004 - Timetrack™ 36 camera digital HD-1 system

Match cuts are simply straight cuts where the action is continuous through the edit. Soap operas and other forms of live television that are shot with multiple cameras often use match cuts to change camera angles.

Chris Marker captured the concept of the match cut using just a single still camera in his famous film made entirely of stills, LA JETEE (1962).

Using a large number of cameras and rapid editing the match cut can function purely as a multi-camera editing technique, as in Lars Von Trier's DANCER IN THE DARK (2000), in which over one hundred video cameras were used to allow for rapid cuts between over one hundred unique fixed perspectives. This set-up allowed scenes with limitless editing possibilities to be shot in one take.

Using Digital Air's camera systems match cuts can naturally blend in and out of smooth virtual camera movement by using sections of cameras which are arranged in curvilinear sequences.

> match cut
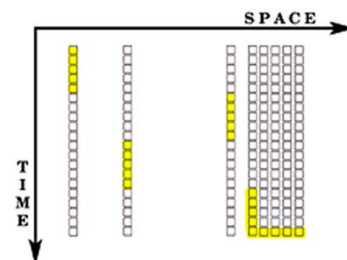
This example of the match cut technique was recorded with 36 Timetrack™ digital cameras recording full frame uncompressed HD images synchronously at 30 fps. Because the cameras were in a circle any frame in the sequence could be turned into a frozen moment.

Three views of the same (approximate) moment in tim in Chris Marker's LA JETEE (1962)

universal capture
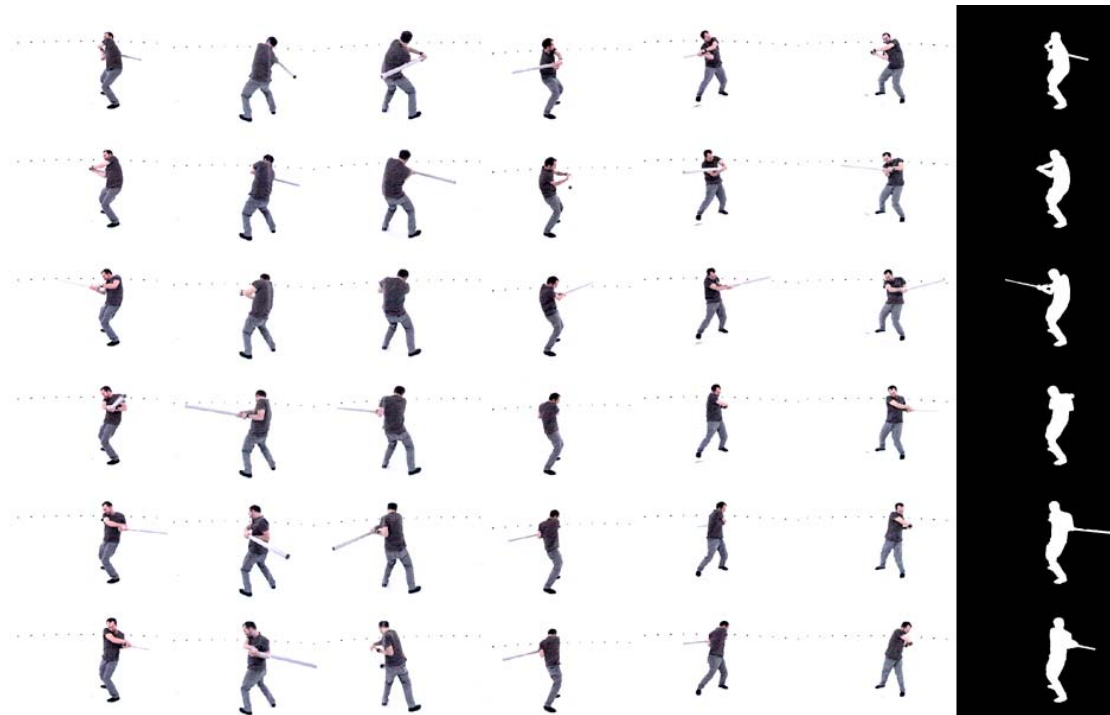
Universal capture test 2004 - Timetrack™ 36 camera digital HD-1 system

Universal capture is a recording process in which we use Digital Air's Timetrack™ high definition digital camera systems to record scenes from dozens of different perspectives continuously and synchronously at 24, 25 or 30fps.

In post production virtual camera movement can then be created simply by switching views.

Multiple takes can easily be composited together and seamlessly transitioned between.

Any instant can be used to create a frozen moment.

Additionally, the multiple viewpoints for every point in time can be used to create a 3D model of the subject. Texture maps (the images themselves) can then be projected back onto the 3D model for photorealistic rendering.

Data from our universal capture process can be combined with CG backgrounds to give the director complete freedom over camera position and movement in post production.

> universal capture
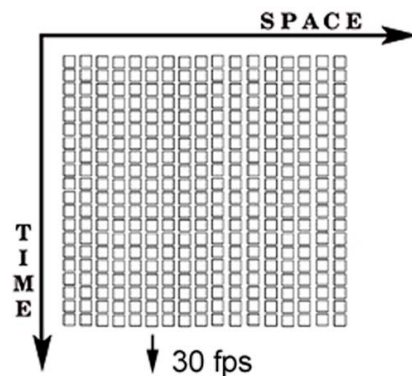
This example of universal capture was recorded with 32 Timetrack™ digital cameras recording full frame uncompressed HD images synchronously to disk at 30 fps. The Macromedia Flash movie on our website (based on the above matrix of images) lets you interactively move the point-of-view around the figure. This works both when the figure is moving and when it is paused.