Art in Motion

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Putting motion into Art requires a different approach to motion control than the typical machine tool application. Although many of the hardware elements may be shared, the motions and how they are coordinated is typically quite different. This divergence starts with artistic requirements, grows through varied development techniques, ending with final experience desired by the artist.

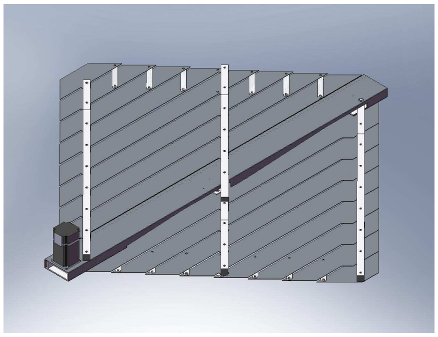
Calgary Zoo Lion – Bleeding Art Industries
Taken during commissioning.

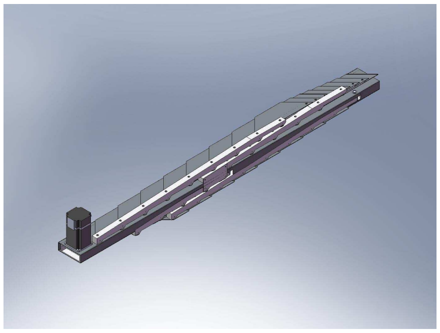
Often times, the motions are only roughly defined while the "creature" or "art piece" is being designed, and then the artist experiments to bring natural motions to life. The various motion capabilities are like the basic colors on the pallet to be mixed. The goals also vary with the artist and the project. Some art is pure fantasy, with the motions based on the whims of the artist. Other artists mix a purpose, such as architecture, with their art. The art can be used to mimic nature, or it may start out imitating the familiar, and then stretch beyond causing an uncomfortable feeling in viewer that causes them to reconsider what they thought they already knew.

Conservation exhibit at the Calgary Zoo asks for support to help improve the animal habitat around the world.
http://www.quicksilvercontrols.com/QCI-CalgaryZooLion.html

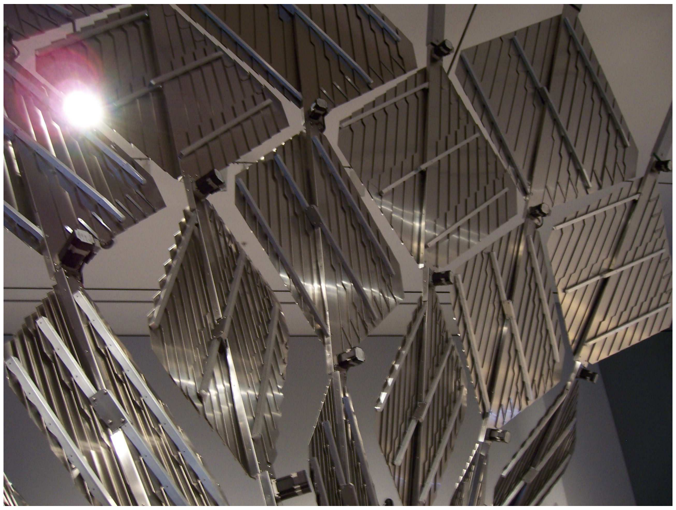
The artist's approach to generating the motions also varies depending upon the usage of the art figures. Amusement parks and museums need the hardware to carry the show without real-time continuous interaction by artist, whereas the motion film industry depends on the real-time artistic interpretation of the puppet masters interacting with the actors to meet the vision of the director. These differences in usages greatly vary the architecture of the motion system and the resulting communications methods.

The motions of an amusement park are first drawn out in basic form to match the desired timing. The overall motion may be guided by the music selected or by other recorded sound tracks, to determine the basic tempo of the show. The motions can then be formed starting with smooth curve sections which are then refined by the artist by stretching and warping the various trajectories to get the desired fluid movements that mimic life – as seen by the artist. The structures being moved are often quite mechanically compliant – trunks, tails, fins – and the motions must be tailored to prevent shocks that will set them wiggling or shaking - unless that is the desired effect! A simple figure may only have 4 or 5 axes, while a more complex art piece may have 15 or more actuators per figure. With multiple figures, the number of coordinated axes can grow rapidly. These motions must be coordinated with the sound tracks, lighting, smoke generators, and other effects.

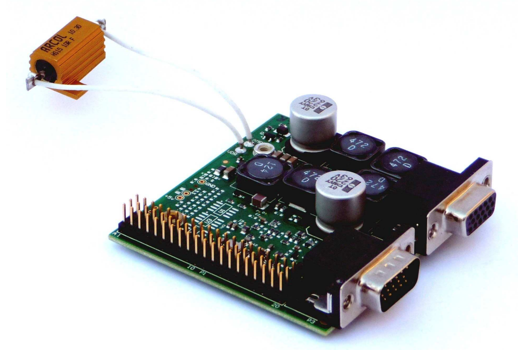

Panel open position


Panel closed position

Fortunately standard stage controllers are able to store and play back the sounds, and control the lights and motions. The lights and motions are commonly controlled by a protocol called DMX512-A (or **ANSI E1.11-2008**). DMX uses a 250k baud serial communications over an RS-485 network. Each burst of data is carried in a "frame", with the data being updated approximately thirty to sixty times per second. Each frame consists of a "break" (extended start bit state) followed by a start byte (to identify the frame), and up to 512 data bytes, each called a "slot". Each 8 bit slot can carry 256 levels of information. This is often adequate for light levels, and some simple motions, but it is a bit limited for fluid motions. Advanced controllers, including those from Gilderfluke (www.gilderfluke.com), are able to combine and manipulate multiple slot data together to as 16, 24, or 32 bit data, allowing greatly improved motion dynamics. The SilverDust™ and SilverSterling™ lines of controllers from QuickSilver Controls, Inc. (www.QuickSilverControls.com) have the ability to collect multiple parameters from the DMX data stream, with each parameter selectable to allow for 8, 16, 24 or 32 bit data in multiple formats, to allow flexibility of motion for each axis.


www.hoberman.com - Emergent Art
Twenty-six panels combined in dynamic art exhibit
http://www.quicksilvercontrols.com/QCI-MoMA.html

The DMX data stream updates approximately 20 to 40 times per second, according to how many devices are being controlled, and thus channels are being sent in the frame. It also varies depending on whether multiple styles of frames (different start bytes differentiate the destinations or uses of the frames) are being mixed within the data stream. These additional frame types can be used to effectively extend the number of devices being serviced, or can be used for diagnostic purposes or to retrieve data from the DMX devices. The DMX data stream does not support retry of a corrupted frame, it just continues on with the next frame. The data corruption should be rare in a well shielded system, but statistics say it is hard to completely avoid. A checksum may be used to detect noisy data by adding the data values from slot 0 through 100,for example, and then sending the next two slots as the sum of those preceeding data points. If the count does not agree with what was received, the controller can then discard the errant data. DMX does not include a means to cause data to be resent, but the time to the next set of data is brief; the corrupted data must just be estimated from the available data. The motor controller/driver is responsible to filter and interpolate the data points across a couple of sample periods to produce smooth motion. The action of the control loop can also be used to help produce more natural motions.


QCI-S2-IG-01 Servo Controller and Driver

The PVIA control system used within QuickSilver Controllers separates the gain terms associated with feed-forward , that is dependent only on the requested trajectory, from the gain terms used for feedback, those dependent on measured motor position, speed, and acceleration. The motion can be further filtered and given a smooth exponential decay by reducing the feed-forward terms, lowering the position feedback gain, and increasing the gain terms used to simulate viscous inertial damping. The resulting smooth exponential decay of motion following transitions better mimics nature than the crisp motions of a tightly tuned control loop typically found in the machine world. Additional channels within DMX can also be used to adjust these control terms dynamically, tightening the control loop for time sequences that need rapid motion, and then loosening it by reducing gains to again produce smooth gliding motions, according to the needs of the artist. Quick motions such as blinking or rapid eye tracking motions use higher control system gains, while slower and smoother for a sliding glance motion of an eye would use the reduced gain terms to enhance filtering. The “glittering” of an eye is actually a series of quick motions with pauses between these motions.

The live action requirements of the Film industry require different approaches to motion control. Rather than capturing and playing the wanted motions of the artist again and again, these art pieces are controlled in real time by skilled puppeteers, often with multiple puppeteers involved in a single character. The live action control allows the character to interact with the actors to create the vision of the director. Multiple takes are often necessary with slight variations introduced each time until the essence of the scene is captured. The ability to interact in real time not only makes the interaction more natural, it also prevents long downtimes with the crew and actors idle while a motion is being reprogrammed. In addition to money and time saved, a fast retake can help prevent distractions related to shadows moving or weather changing when shooting on scene.

The puppeteers commonly use Radio Control (R/C) consoles to control the action of the robotic characters. Advanced R/C controllers are highly programmable, having the ability to blend multiple sources, set motion and rate of change limits, and otherwise mix multiple channels from the classic joy stick inputs. These multiple data sources are converted to pulse width coding and multiplexed in time to allow the signals to be transmitted, either by radio or wire, to the receiver. A single RC controller can typically handle from four to as many as 15 actuators. At the receiver, the signal is demultiplexed to a series of connectors, with power, ground, and a PWM signal in a 3 pin connector to each axis.

The standard R/C controllers and motors nominally use a 1 to 2 millisecond pulse width, 0 to 3.3v, to indicate the desired value, be it position or speed, although some can use the extended 0.7 to 2.3 millisecond timing. For the nominal timing, a 1 millisecond pulse indicates extreme motion position or velocity in one direction, a 1.5 millisecond pulse represents centered or stopped, and a 2 millisecond pulse indicates the opposite extreme position or direction of motion. The receiver provides the demultiplexed PWM signal to each axis, updating each approximately every twenty to thirty milliseconds. More sophisticated controllers will retain the latest received command in the case of loss of signal, to prevent a change until the signal is reacquired. Smaller axes may be handled by the conventional small R/C servos typically seen in model airplanes. Larger power axes need the PWM signal to control higher power controllers. The SilverDust™ controller has recently introduced PWM pulse width capture capability, allowing direct R/C control. This capability is currently being used in a robotic figure using a dozen 200 lb actuators in a movie still being shot as this article is being written!