Capture, Identify & Calculate 3-D Motion

What: Describing Motion Quantitatively
Who: Biomechanics, Inc.
How: Multiple MaxVideo 200s, Analog Scanners, ImageFlow

Technical Summary: *Multiple cameras attached to a multi-MaxVideo 200 system performs thresholding and logic operations on images acquired from reflective markers located on human subjects. Featurelists of the marker edges are generated and passed to graphics processing engines for automatic tracking, dynamics analysis and real-time animation of synthetic characters.*

For over a decade, Biomechanics, Inc. of Marietta, Georgia has applied increasingly powerful Datacube image processing equipment to the challenging task of quantitatively describing human movement.

The task of quantifying motion, especially that produced by humans, has been attempted for a number of years with increasingly sophisticated tools. Motion data is used for analysis in areas such as sports and medicine, and in the entertainment industry, for the purpose of recreating motion in different settings to produce animation and special effects.

Earlier approaches attempted to quantify movement with high-speed pin-registered film cameras, manual digitization, and simple mechanics models. Because of the subtle complexities of human movement, the results of these earlier methods were unsatisfactory. As newly available computer technology was applied to the problem, results improved, but not enough for many applications.

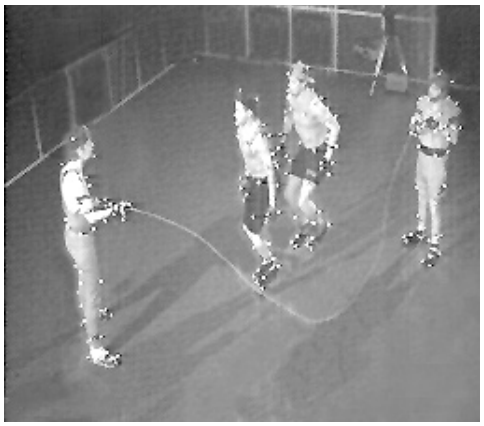
For the past decade, Biomechanics has combined high-bandwidth Datacube hardware and software for real-time image data acquisition and analysis, with other proprietary processing engines that generate the anatomical models, and dynamics data that drives the 3-D graphics models. Biomechanics has earned an industry-leading position in enhanced-motion video games and animation with:

- Exceptionally accurate mathematical models of human anatomy
- A mechanics approach that determines 3-D kinematics and kinetics data
- Sophisticated 3-D graphics animation software

Significant challenges had to be overcome to develop this technology. For example, a full three-dimensional analysis of the subject had to be acquired using techniques that were strictly non-invasive (i.e., had no impact on the motion being tracked). In addition, achieving the desired levels of spatial and temporal resolution required large volumes of rapidly renewed, accurately sited data from a number of cameras to be generated and analyzed. Datacube's high-bandwidth pipeline image processing constituted an essential part of Biomechanics' solution.

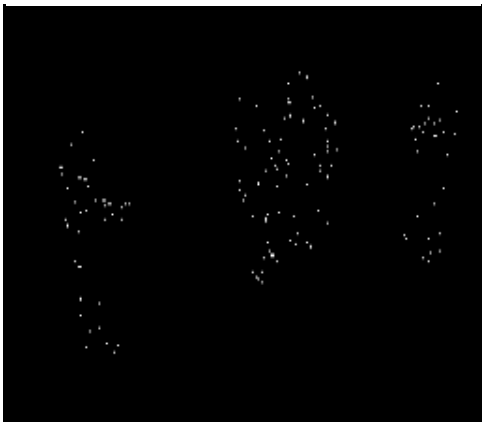
The Biomechanics process involves a complex systems mechanics approach to analyzing the human body, animals, mechanisms, etc. As a result, the system can track and identify reflective markers placed anywhere on the subjects' body segments (on skin, clothing, bodysuits, etc.). Markers need not be placed near estimated joint centers as required with less sophisticated approaches.

As subjects move, multiple video cameras attached to the Datacube hardware capture their motions. Virtually any motion, including rolling on floors, aerial acrobatics, interactions/collisions with other subjects, etc., can be captured without wires, electronic hardware or other impediments on the body. Whether performing in small or large spatial volumes, the Biomechanics system takes advantage of Datacube pipeline processing bandwidth to capture, identify and calculate the 3-D motions of as many as several hundred markers with unrivaled accuracy.



Above: Models with reflective markers act out a series of movements.

Below: Image from above after threshold filtering shows only the markers.



Biomechanics' proprietary full-body complex systems mechanics approach uses the captured marker information to generate true 3-D full-body dynamics data, which can then animate synthetic characters that precisely imitate the subject's movement. The motions created are thus based on both rigid and non-rigid body dynamics, rather than simple joint-origin-based mechanics. The scientific approach employed and the accuracy of the dynamics data generated combine to produce startling realism and a highly lifelike quality of motion.

Biomechanics is widely recognized as the world leader in this area within the field of entertainment. Building on this success, Biomechanics now offers its technology to other areas such as defense/aerospace, medicine, sports, robotics, and other industries where the technology is applicable.

Over for technical details

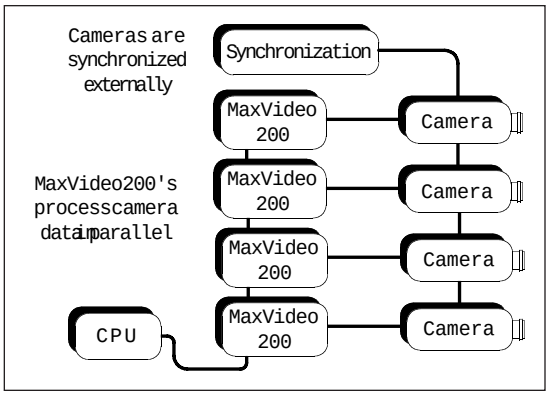


Figure 1: System Configuration

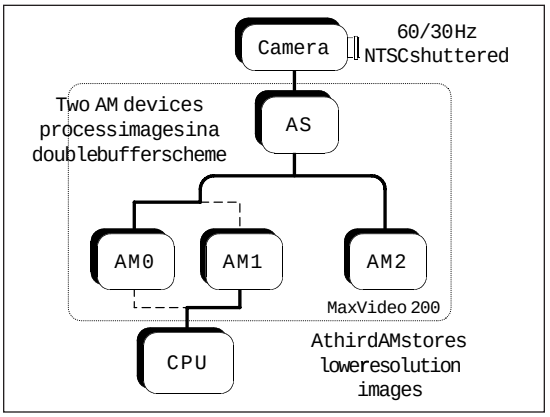


Figure 2: MaxVideo 200 Configuration

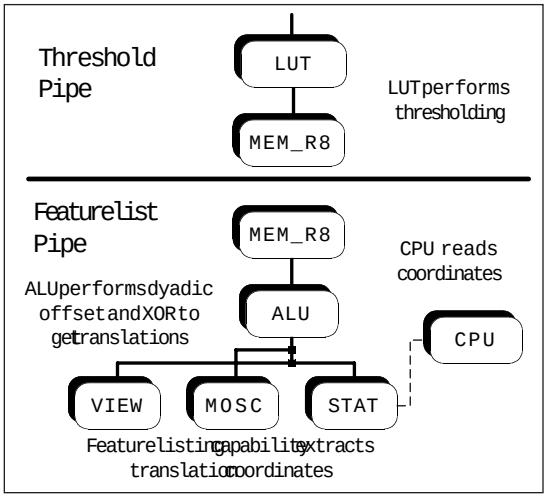


Figure 3: AM0/AM1 Configuration

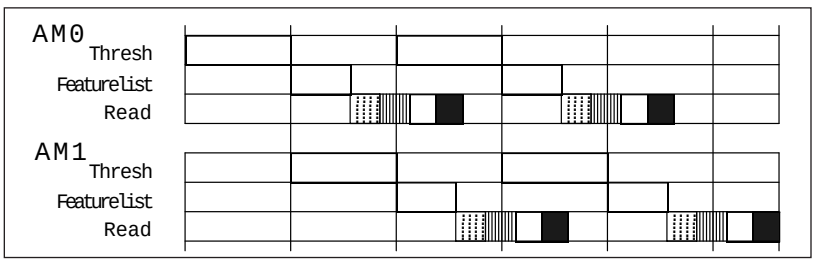


Figure 4: Acquisition Timing

Subjects wearing reflective markers move within a controlled-lighting environment, where they are imaged by several high-resolution cameras positioned at various angles and heights. A system running Datacube's ImageFlow software uses multiple MaxVideo 200 image processing sub-system boards, each dedicated to a single camera, to perform thresholding and logical operations on the incoming images before generating a featurelist of the marker edges. This list of coordinates is then passed via a VMEbus to automatic tracking, dynamics, and graphics processing engines supplied by other manufacturers.

Datacube's AS (Analog Scanner) device provides a flexible, accurate digitization interface. The high bandwidth of the Datacube system coupled with the precise management functions of ImageFlow's Event Manager ensure that problems with missed frames or unsynchronized processing are addressed and solved.

Image data from a single camera is digitized by the AS and the odd and even fields are stored in separate Advanced Memory (AM) devices (VSIMs), as shown in *Figure 2*. This separation of fields is possible because of the MaxVideo 200's exceptional power and flexibility. It reduces the processing latency by about 16 ms. Simultaneously, XY PATS are used to tile frames in AM2 (a 16 MB AM) as lower-resolution images.

While the data from one field is being stored, the data from the previous field is thresholded *(see Figure 3)*. Threshold images are effectively "run-length encoded" by XORing ("Exclusive-Or" function) the current pixel with the previous pixel, generating a bright pixel only when an edge of the binary pixel is found. The featurelist capability of the AM then locates these edges, with the host CPU reading back locations.

The processing of even and odd images is interleaved between two AM devices (AM0, AM1), as shown in *Figure 4*. Since there is only one CPU, one read operation per board is performed to extract the segment endpoint coordinates.

Multiple Cameras, Multiple Subjects

Successive generations of systems have reduced data requirements for each marker, increasing the number of markers and subjects that can be tracked and modeled simultaneously. The current generation can simultaneously track over 500 markers placed on six or more subjects from multiple cameras. In addition, single subjects can be captured, tracked, analyzed and graphically displayed, completely in real time at 60 Hz.

Biomechanics' modeling techniques and advanced motion editing software capabilities have been advanced to support human and non-human subjects. The result is a flexible core technology that can now serve users, not only in entertainment, but also in other industries such as medicine, sports, defense/aerospace, and robotics.

Biomechanics, Inc. can be contacted at:
200 North Cobb Parkway, Suite 142
Marietta, GA 30062
Tel: (770) 424-8195 Fax: (770) 424-8236
email: biomech@crl.com
www: http://www.crl.com/~biomech/