Biomechanics for the 21st Century

by
Gideon Ariel, Ph.D.

MOVEMENT ANALYSIS CAN BE APPLIED TO:

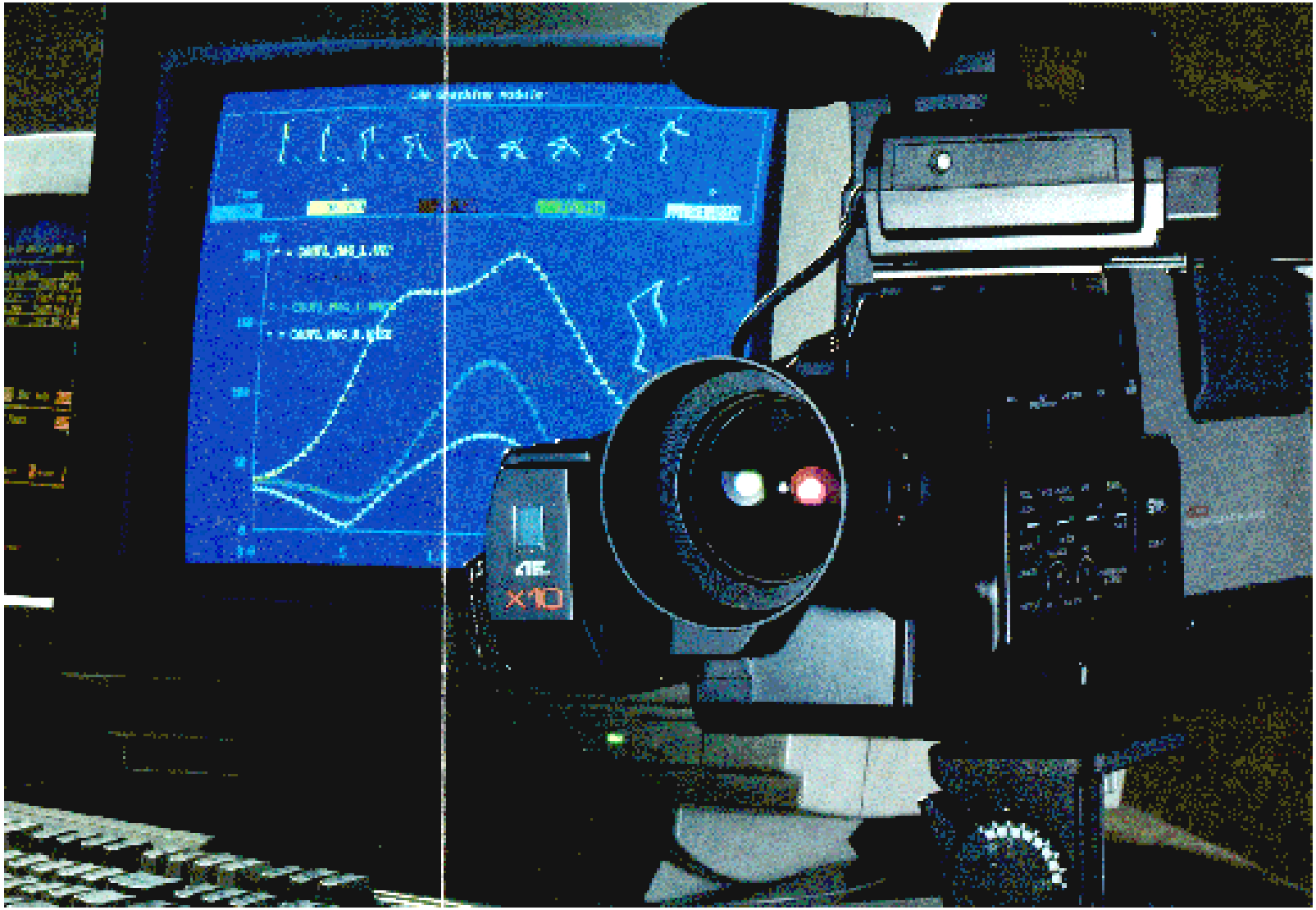
Athletics

Industry

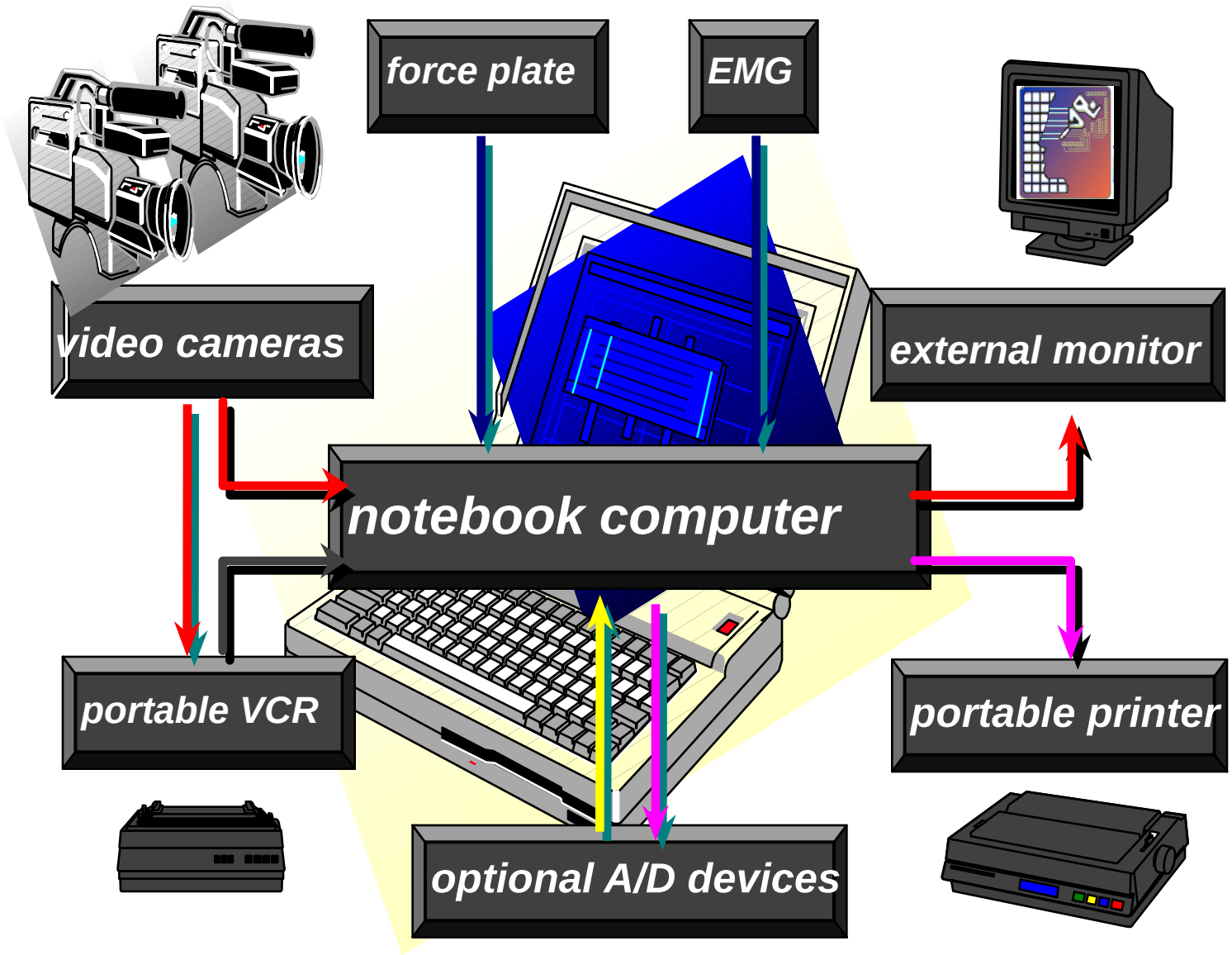
Medicine

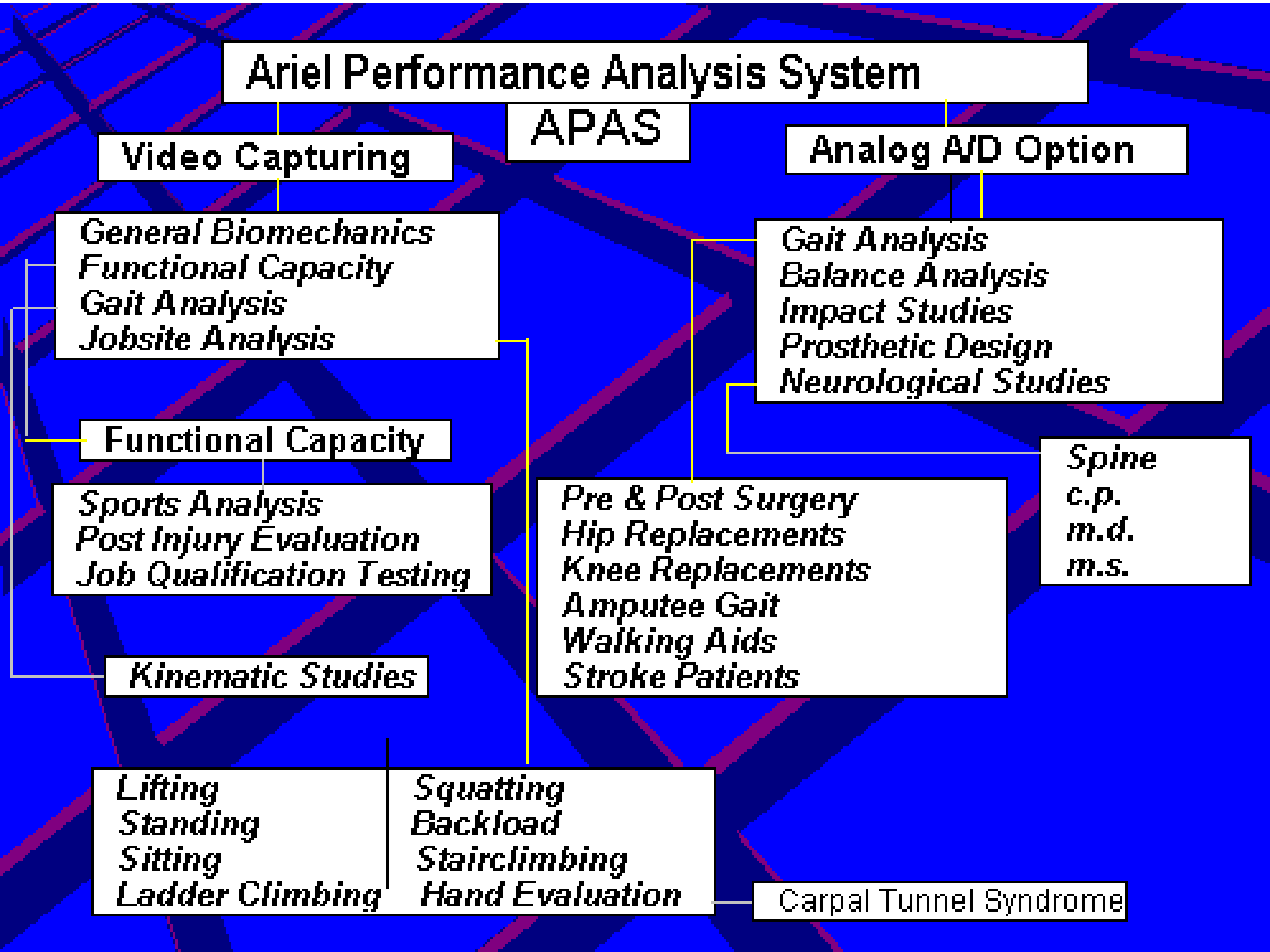
Space

ALL APPLICATIONS UTILIZED SIMILAR QUANTIFICATION TECHNIQUES



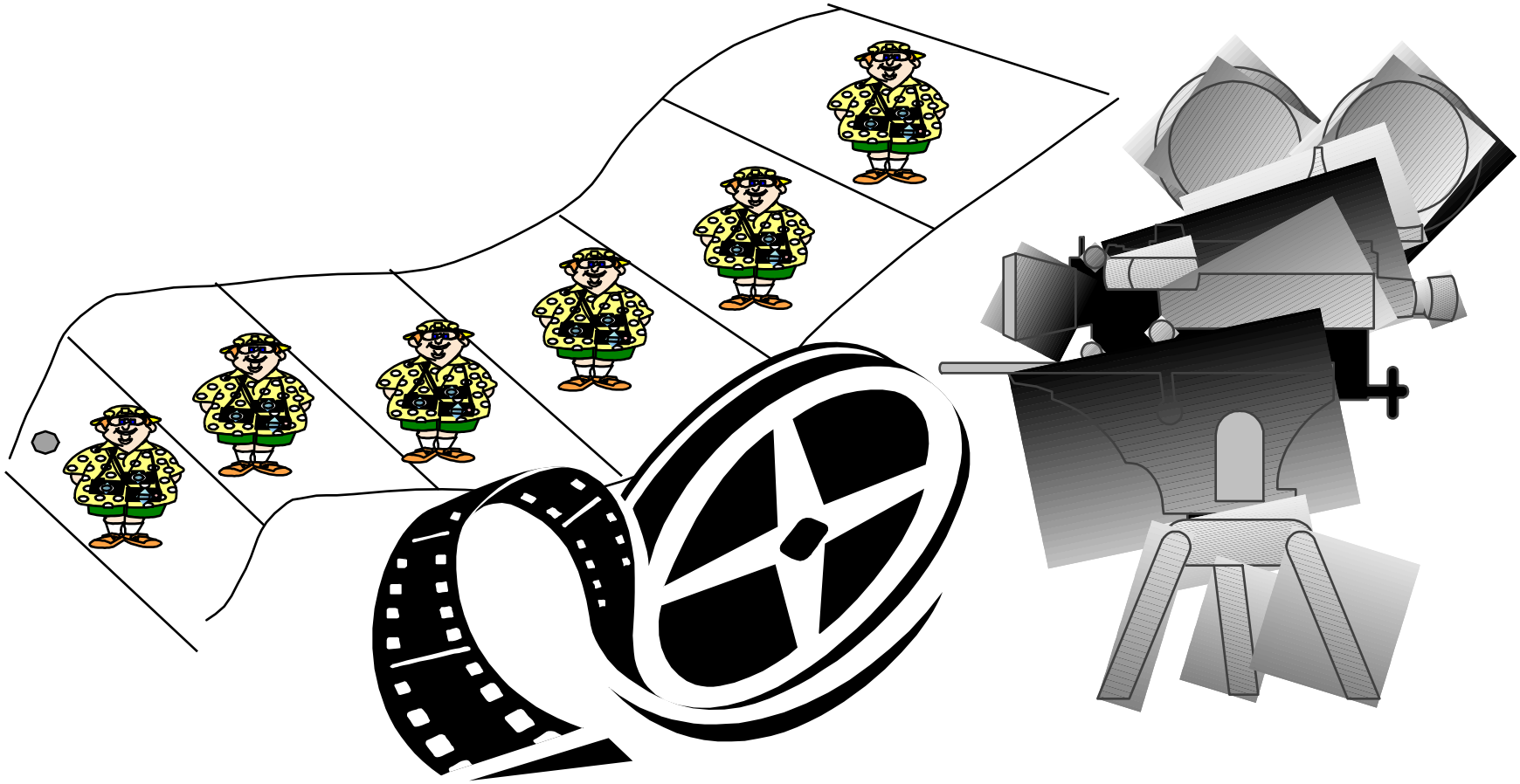
Basic Components of Motion Analysis System




Ariel Performance Analysis System
APAS
Video Capturing
Analog A/D Option
General Biomechanics
Functional Capacity
Gait Analysis
Jobsite Analysis
Gait Analysis
Balance Analysis
Impact Studies
Prosthetic Design
Neurological Studies
Functional Capacity
Spine
c.p.
m.d.
m.s.
Sports Analysis
Post Injury Evaluation
Job Qualification Testing
Pre & Post Surgery
Hip Replacements
Knee Replacements
Amputee Gait
Walking Aids
Stroke Patients
Kinematic Studies
Lifting
Standing
Sitting
Ladder Climbing
Squatting
Backload
Stairclimbing
Hand Evaluation
Carpal Tunnel Syndrome

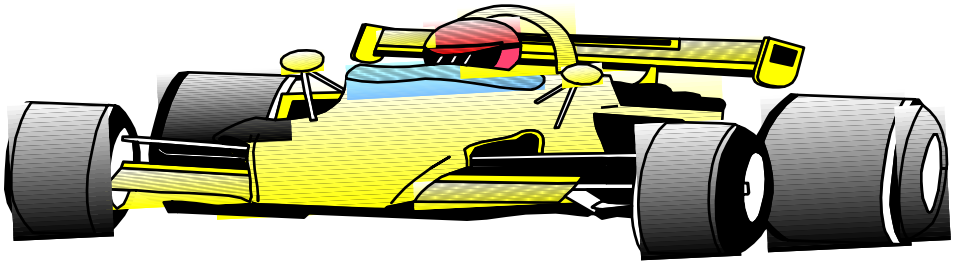
The Early 70's

use of high speed cinematography



NEW TECHNOLOGIES

For Your Professional Toolbox

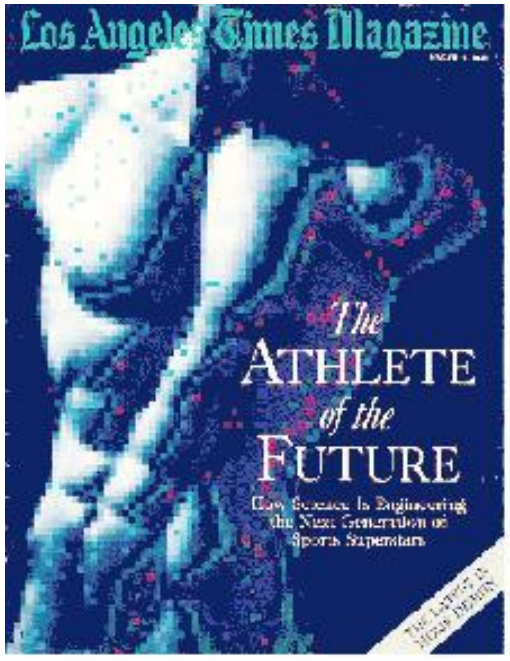


- Computerized Video Analysis [Kinematics]
- Force Plate [Kinetic Ground Reaction] 3D
- Dynamic EMG
- Internet Interface

Analysis of Performance Require:

Video Recording
Digitizing the Data
- **Manual**
- **Automatic**

Transformation of the Data
- **2D - Two Dimensional**
- **3D - Three Dimensional**



KINEMATIC PROCESSING STEPS

- DATA ACQUISITION
- FRAME GRABBING
- TRANSFORMATION
- SMOOTHING
- DATA ANALYSIS

History was made at the Atlanta Games by utilizing the Internet to provide Biomechanical data immediately for use at remote sites

The purpose of the research conducted at the XXVI Olympiad in Atlanta was to expand the biomechanical applications and the interactive capabilities of the Internet to make sport performances rapidly available to everyone

Under the auspices of the International Track and Field Coaches Association, the track and field events which were performed at the Atlanta Olympics in 1996, were selected to illustrate these procedures because these activities uniquely captivate an enthusiastic world-wide audience

- **Because of the strict accessibility to the field for security reasons, special locations had to be chosen and guarantee for setting video cameras.**
- **The main goal in the present study was to be able to load the data in to the Internet at the fastest time, so scientists, students and any interest group will be able to download the video and other data immediately from the Internet.**

- **The purpose of the present study was to analyze Track and Field performances in the Atlanta 1996 Olympic Games.**

- **This was a new and innovative procedure that allows immediate sending of video information all around the world for immediate analysis at different locations**

A BIOMECHANICAL STEP ONTO THE INTERNET

It is a window on the ever-expanding world of on-line information. The new communication links afforded by rapid satellite/computer exchanges bringing together hypertext multimedia and global networking. The Web is growing at an astounding rate and is changing the scientific world by making it possible for anyone to transmit and receive information around the world.

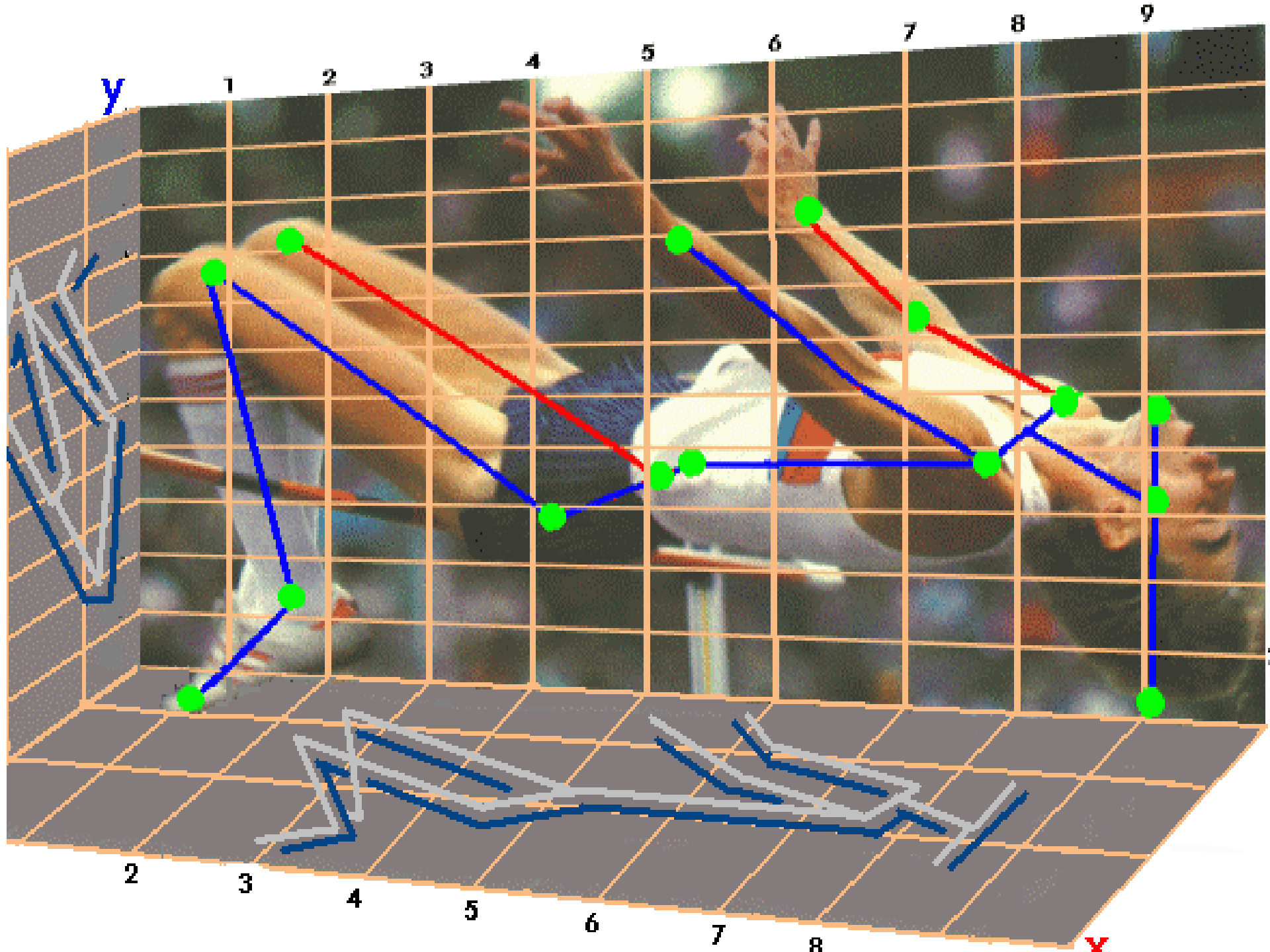
A

Video Recording
and
Digitizing the Data

Reidel Gold Medal

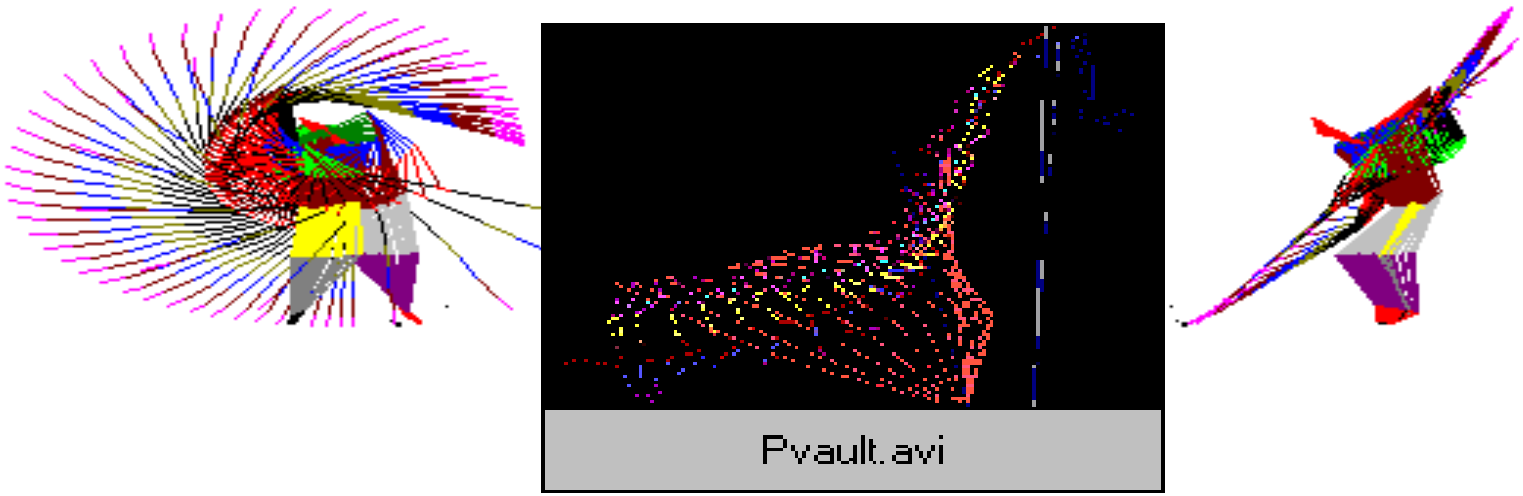
Ridel_rear_adj.avi

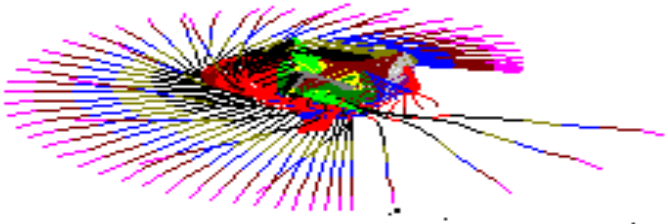
reidelside.avi

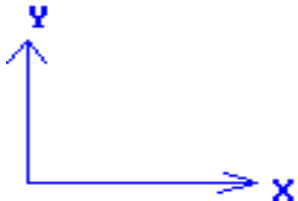

y
1
2
3
4
5
6
7
8
9
2
3
4
5
6
7
8
x

Data Transformation

VIEWING Module C.B.A. Inc.

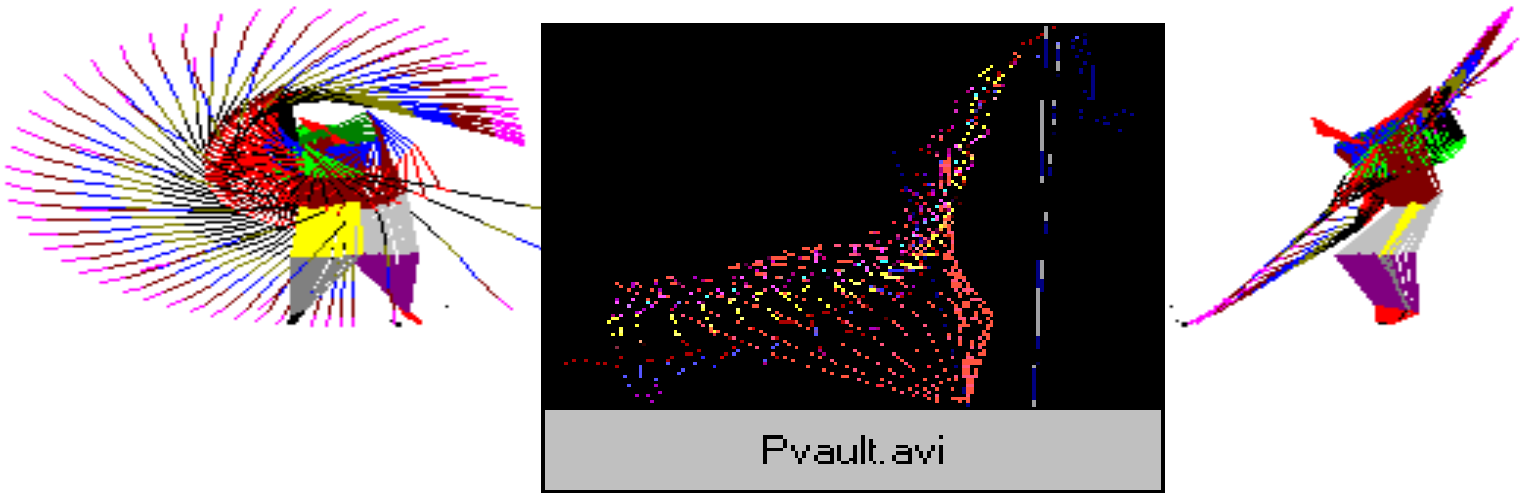


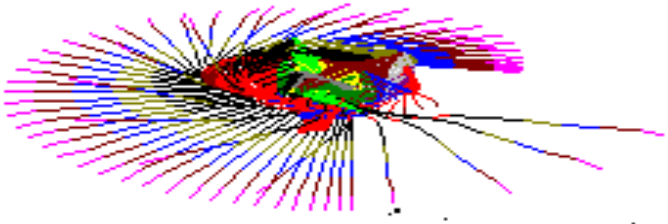


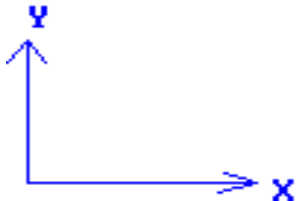


Data Transformation

VIEWING Module C.B.A. Inc.

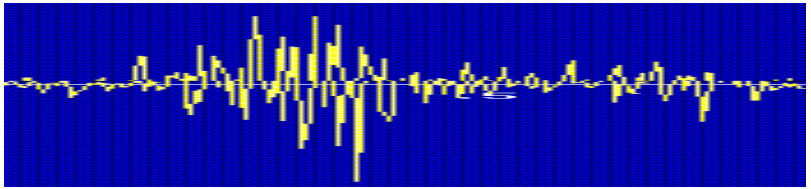






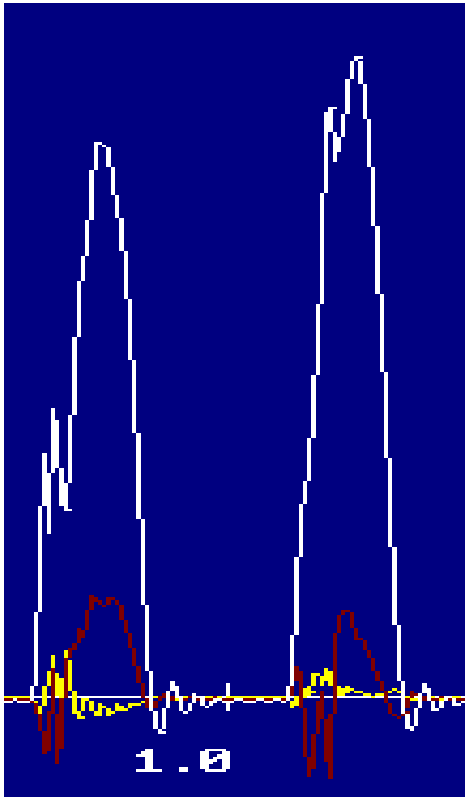
Smoothing of the Data

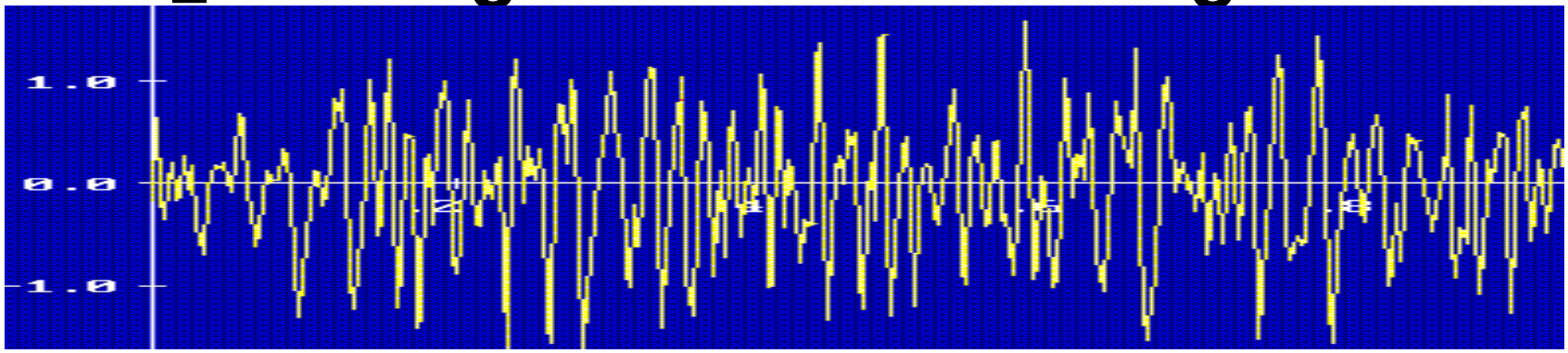
- Filtering Algorithms
  - Cubic Spline
  - Digital Filter
  - Quintic Spline
  - Fast Fourier Filter
  - Segment Constraint

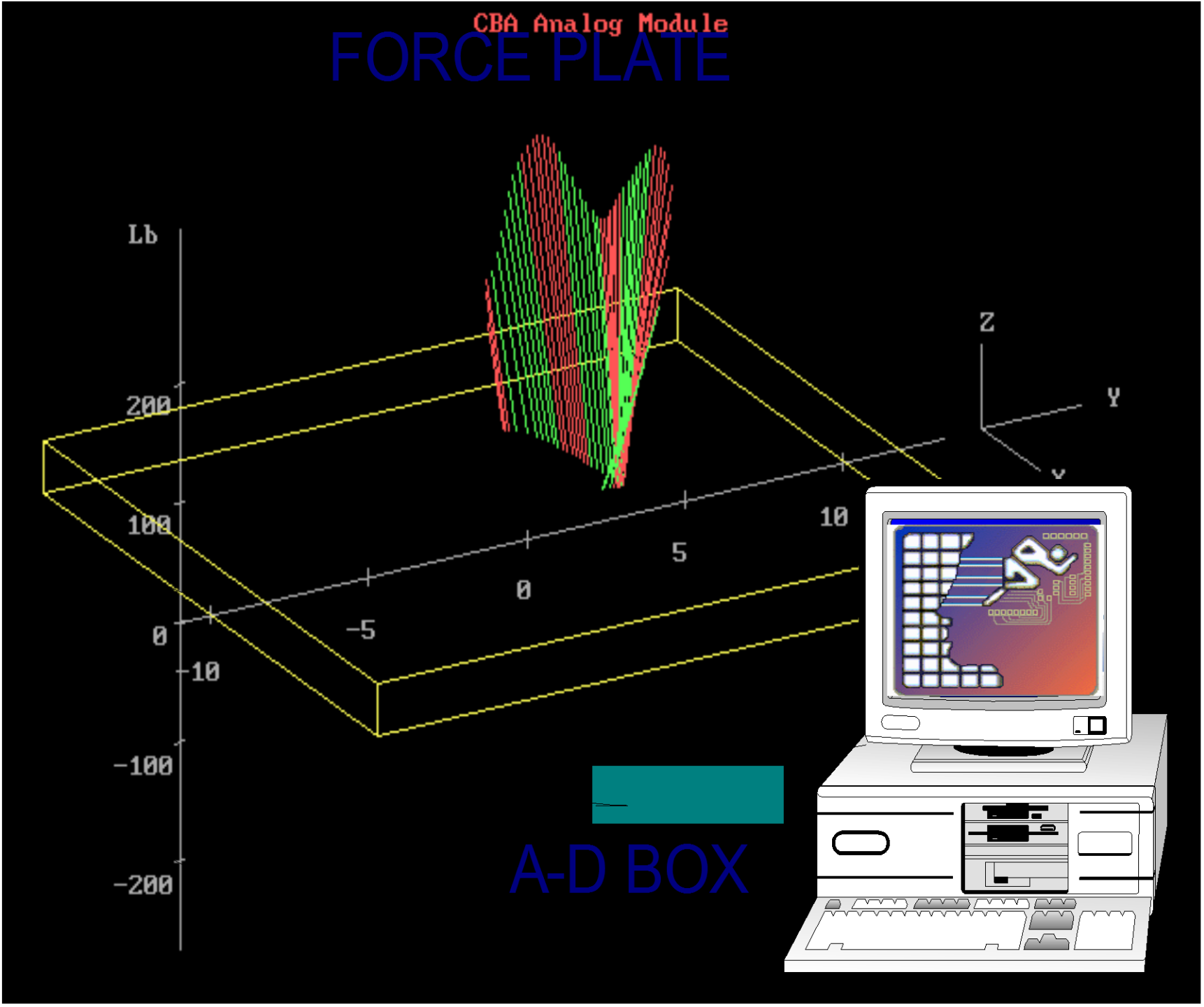


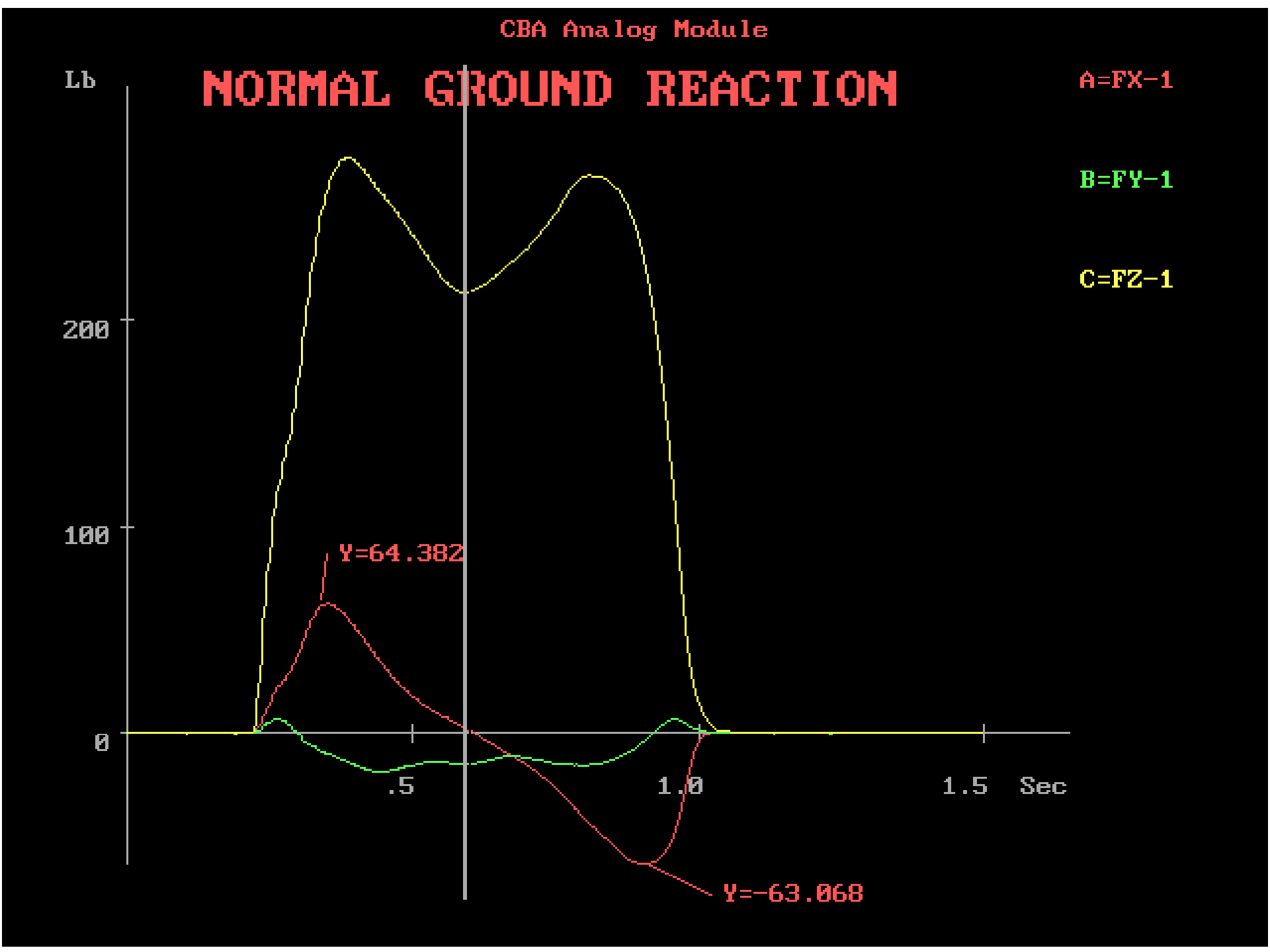
KINETIC
FORCE PLATE
GROUND REACTION FORCES

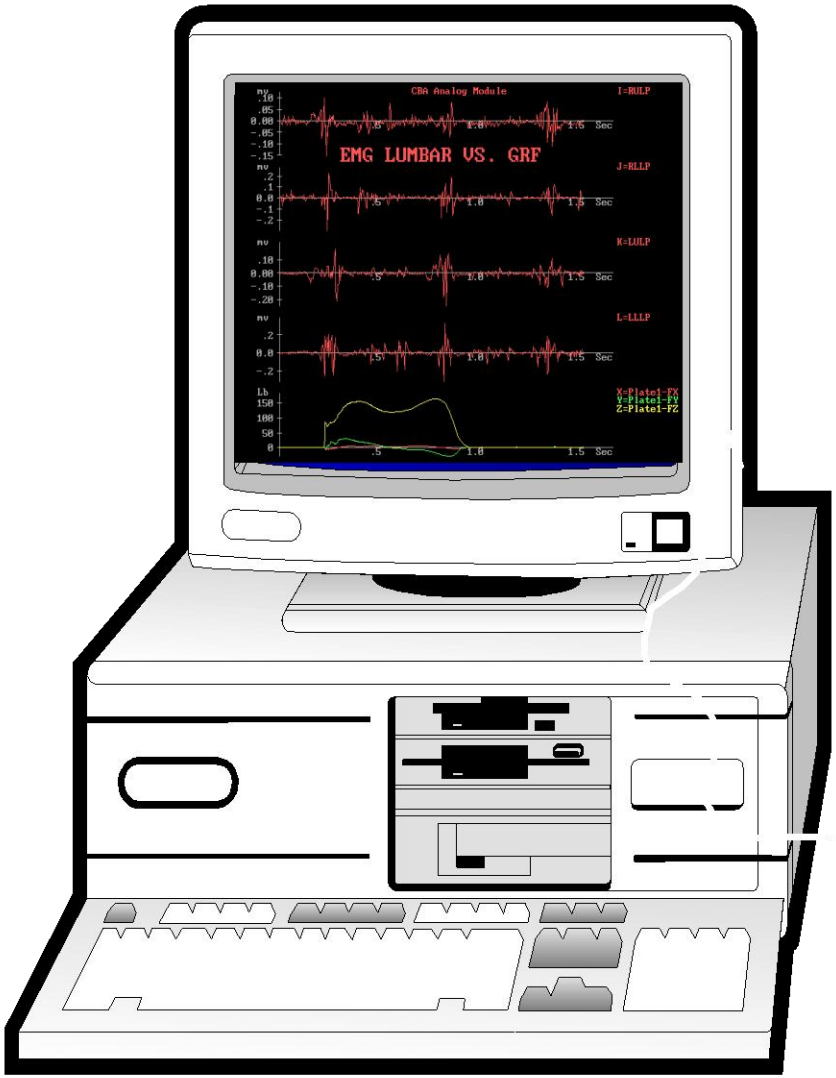
- Analog Data Input
  - Force Plates
    - Horizontal force
    - Lateral force
    - Vertical force
  - EMG Data
    - Muscle Activity
    - Timing of Muscular firing



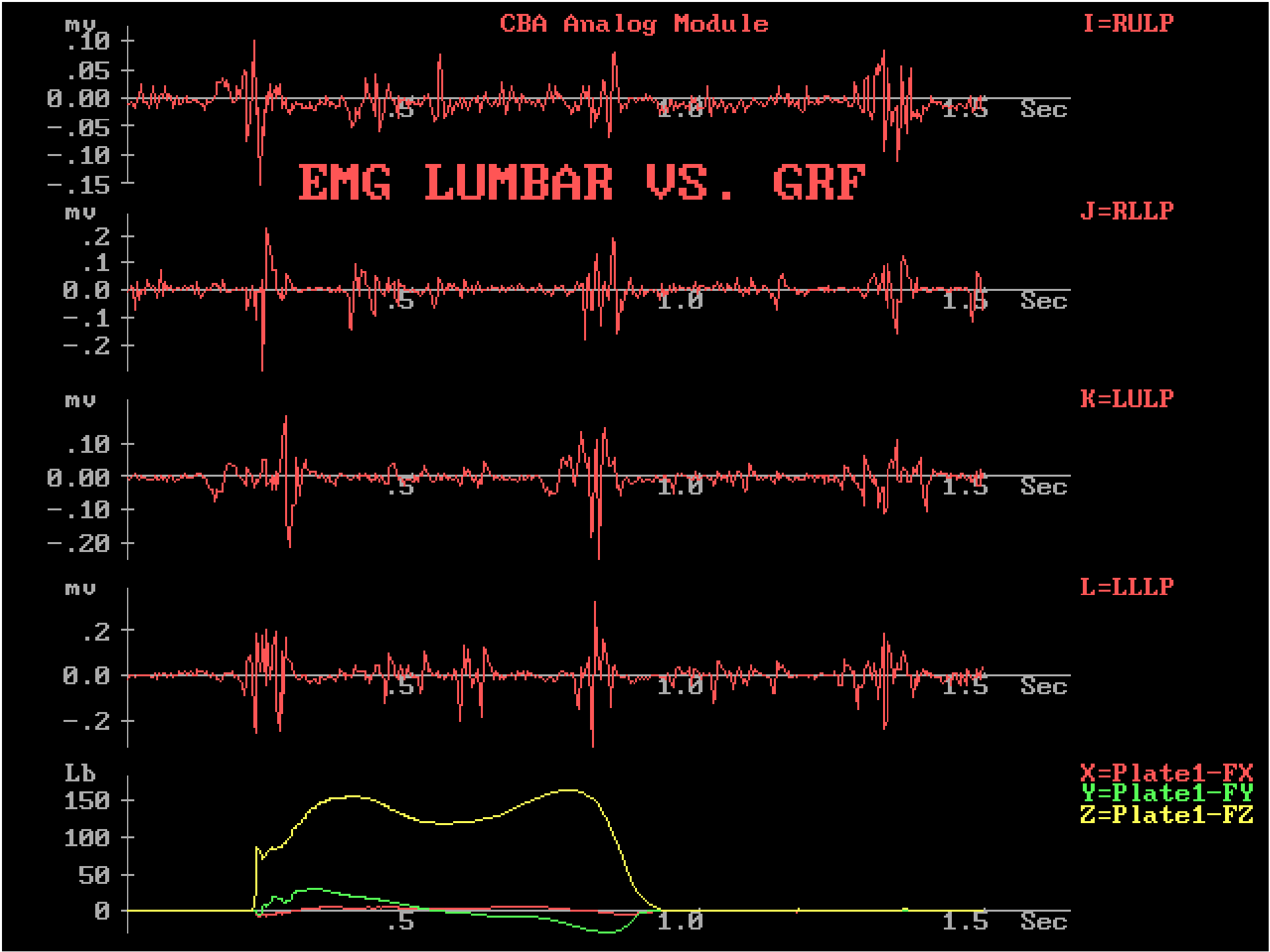


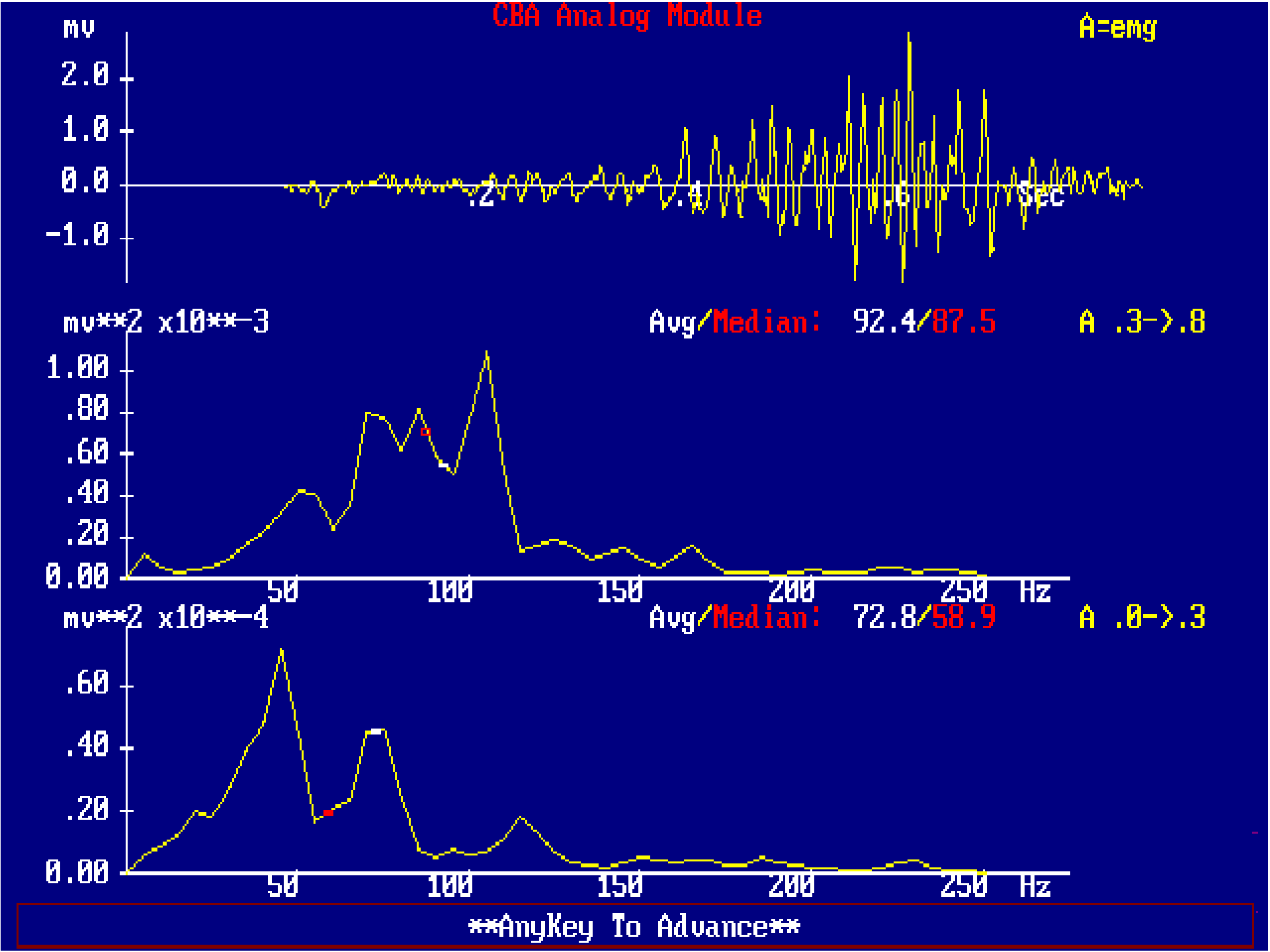

CBA Analog Module
FORCE PLATE
Lb
200
100
0
-100
-200
-10
-5
0
5
10
Z
Y
X
A-D BOX

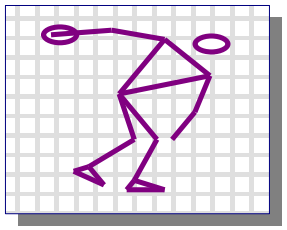

CBA Analog Module
NORMAL GROUND REACTION
Lb
A=FX-1
B=FY-1
C=FZ-1
200
100
0
Y=64.382
.5
1.0
1.5
Sec
Y=-63.068



Capability of Monitoring 32 Channels of EMG


CBA Analog Module
EMG LUMBAR VS. GRF
I=RULP
J=RLLP
K=LULP
L=LLLP
X=Plate1-FX
Y=Plate1-FY
Z=Plate1-FZ
mv
Lb
Sec
.5
1.0
1.5


CBA Analog Module
mv
2.0
1.0
0.0
-1.0
A=emg
.2
.4
.6
.8
sec
mv**2 x10**-3
Avg/Median: 92.4/87.5
A .3->.8
1.00
.80
.60
.40
.20
0.00
50
100
150
200
250
Hz
mv**2 x10**-4
Avg/Median: 72.8/58.9
A .0->.3
.60
.40
.20
0.00
50
100
150
200
250
Hz
AnyKey To Advance



INTERNATIONAL CENTER FOR BIOMECHANICAL RESEARCH

PHOTOGRAMMETRIC TRANSFORMATION WITH PANNING

K.A. Stivers, G.B. Ariel, J. Wise, M.A. Penny, A. Vorobiev, A. Gouskov, N. Yakunin

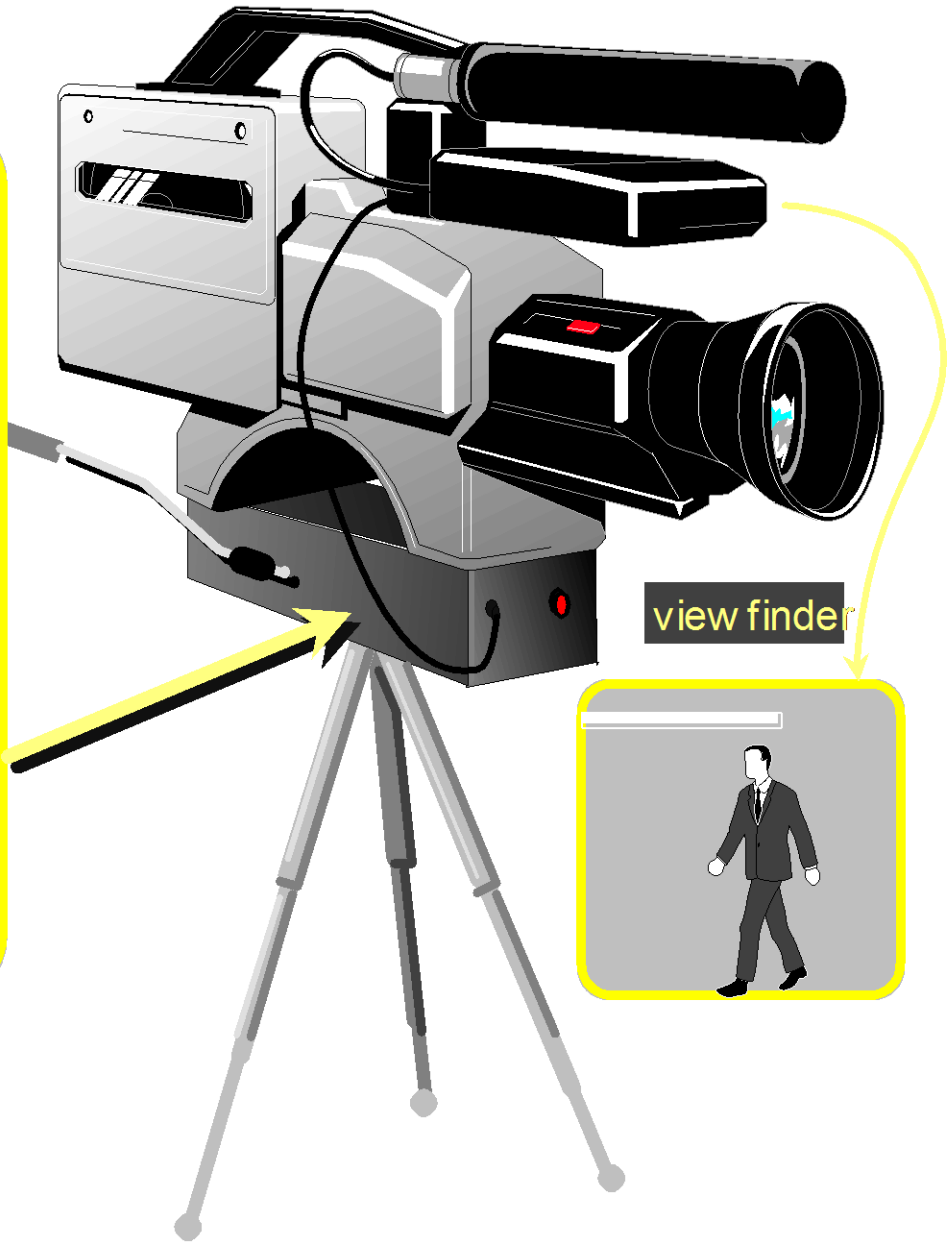
Panning Head

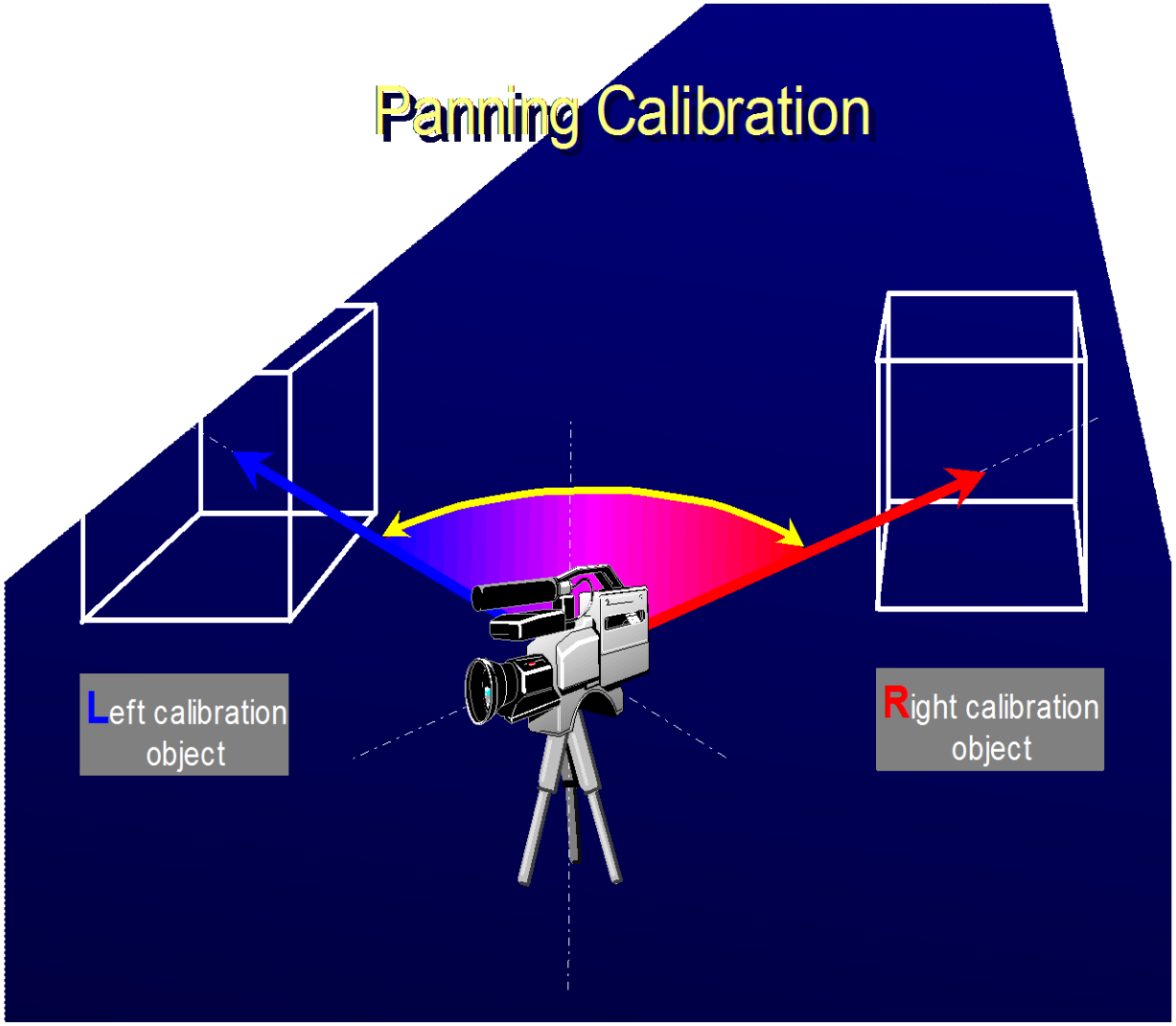
optical angular encoder

selection of the bar width and position within the frame

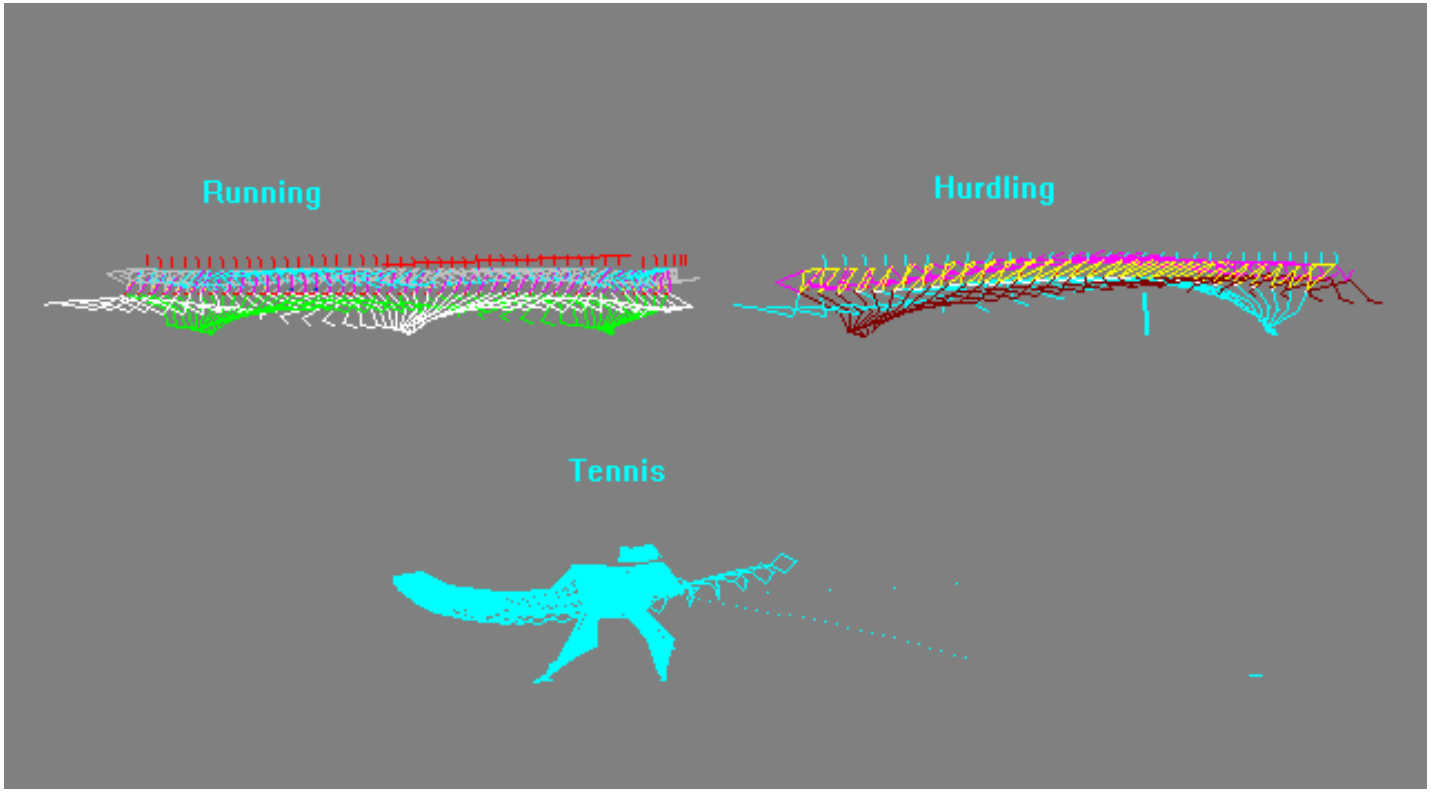
transformation of the encoder impulses to the video signal - the bar with proportional to the panning angle length

video output to the camera's EVF/Character Generator Terminal




Panning Calibration
Left calibration object
Right calibration object

Athletic performances can be divided into a wide spectrum of activities.

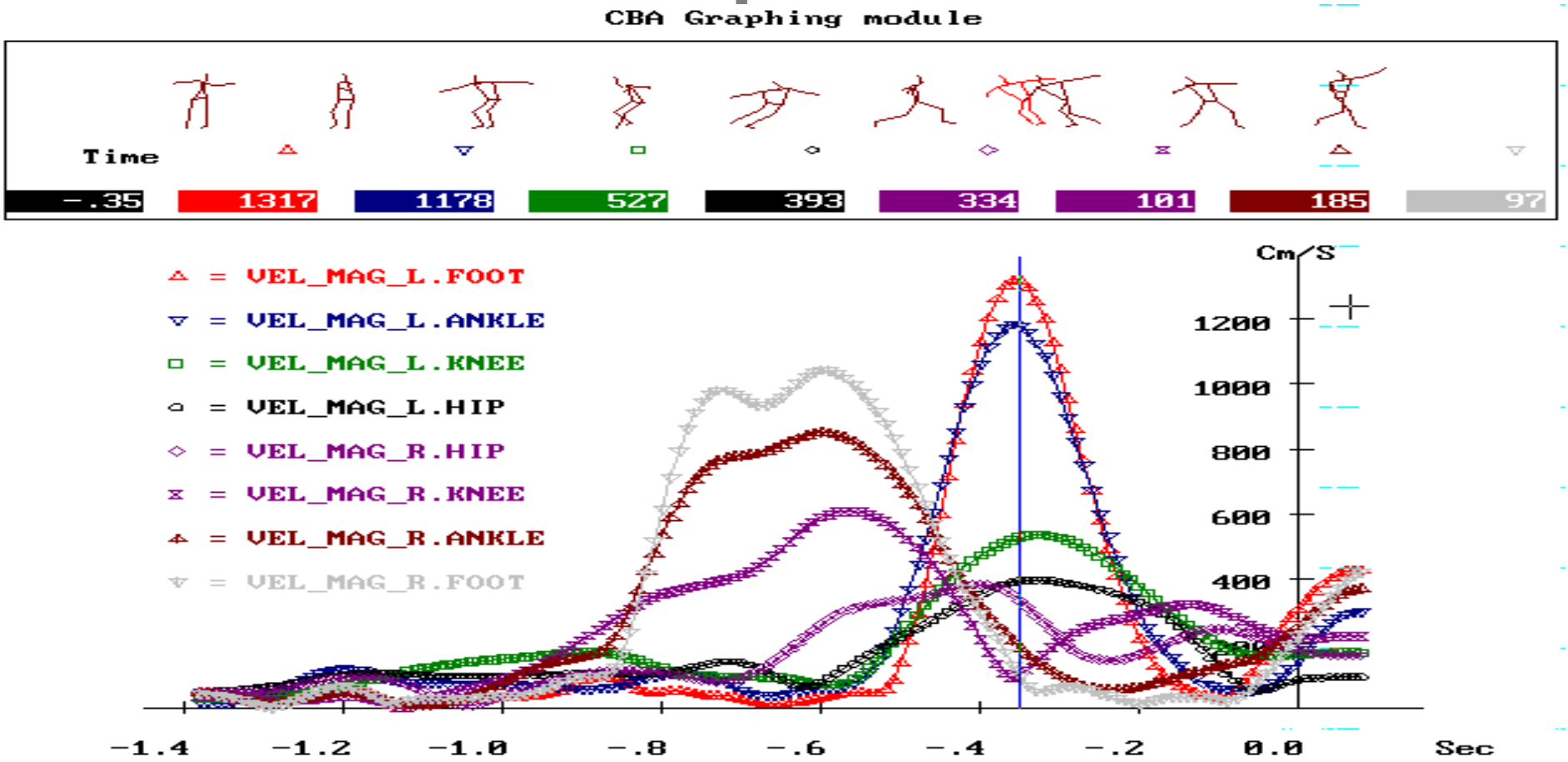


Video of Activities

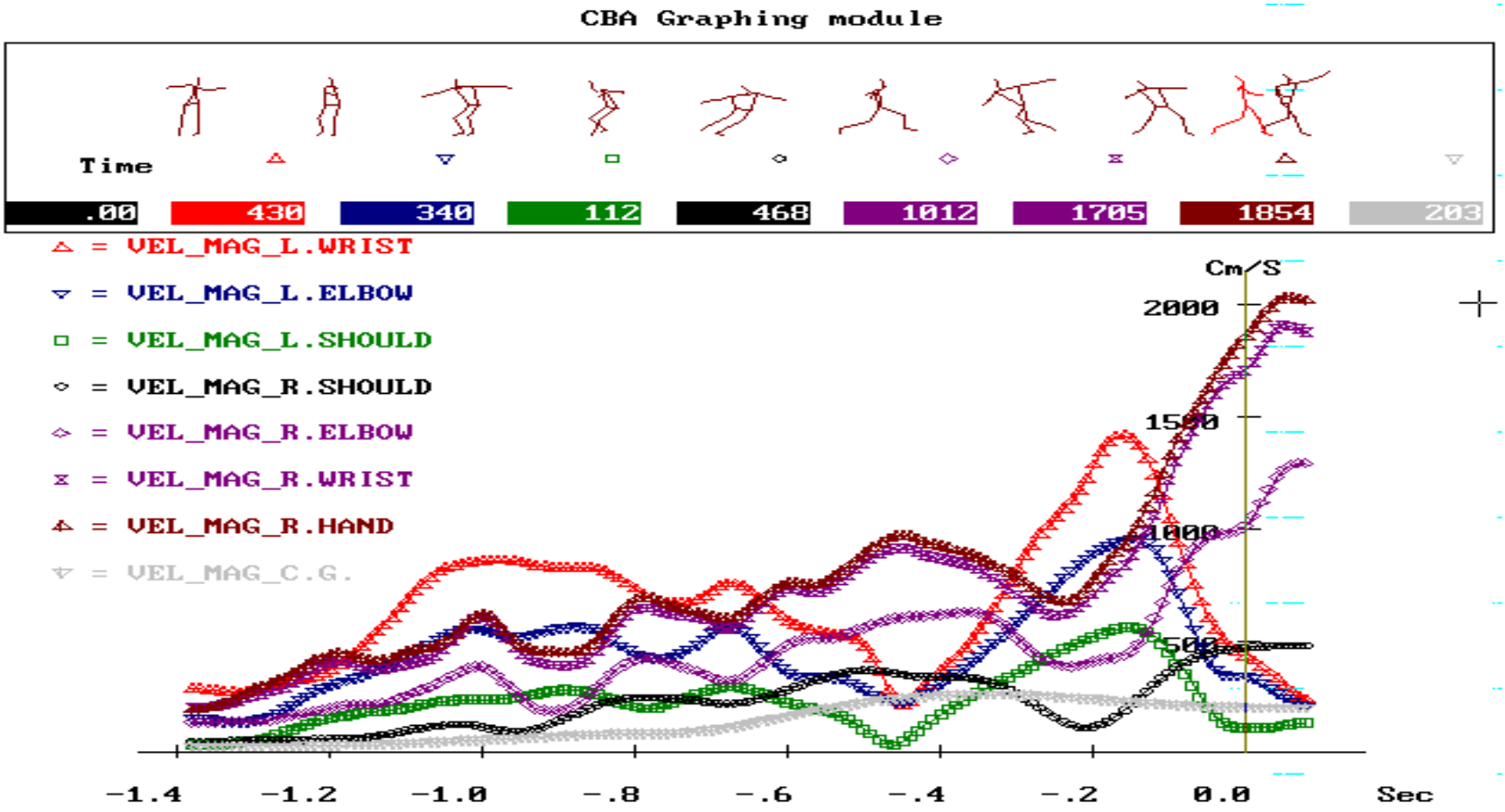
- Explosive Events
  - Throwing
  - Sprinting
  - Jumping
- Endurance Events
  - Long Distance Running
  - Swimming
  - Cycling

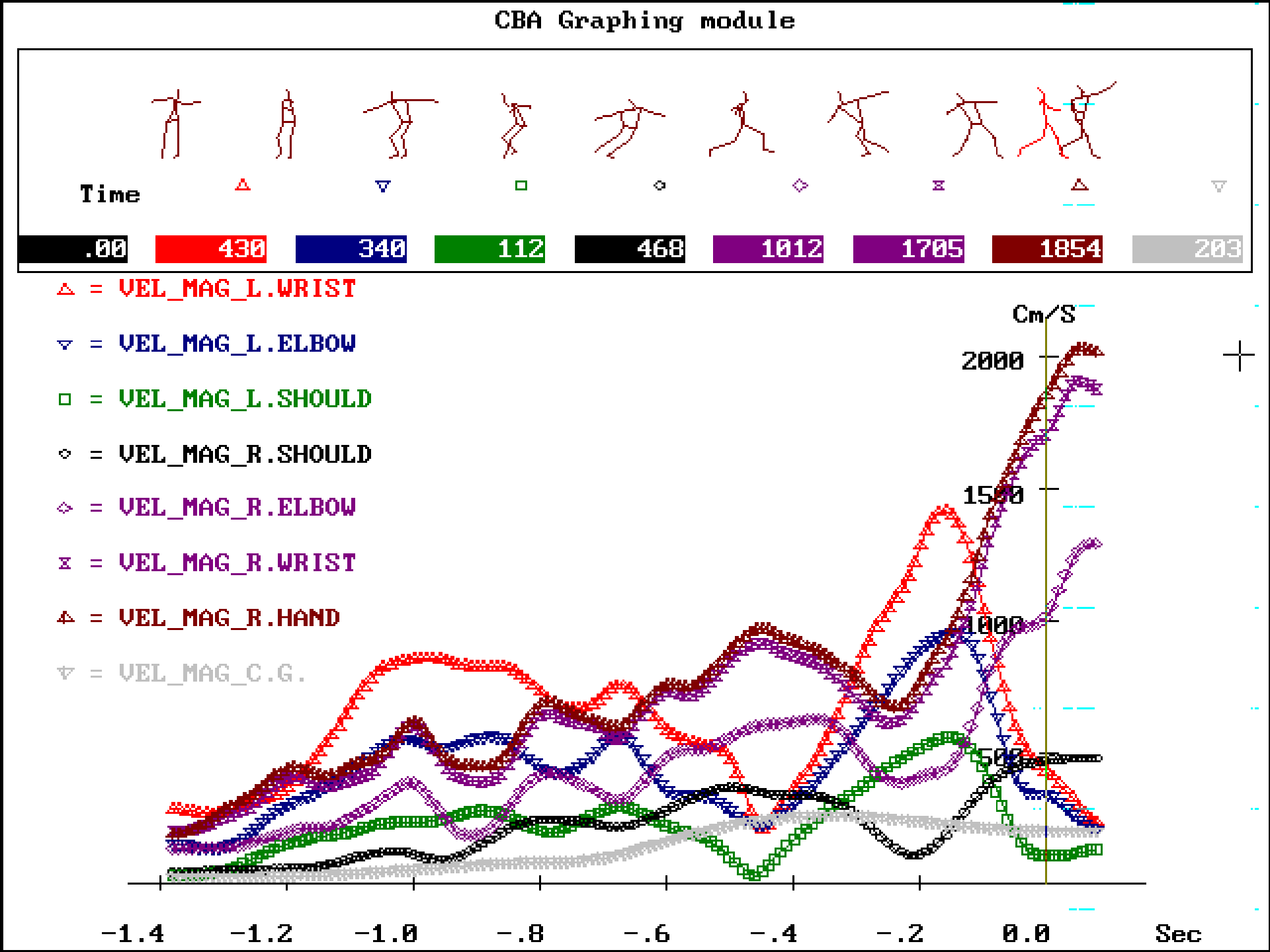
- Esthetic Events
  - Figure Skating
  - Diving
- Team Sports
  - Soccer
  - Basketball
  - Ice Hockey
- Accuracy Events
  - Archery
  - Shooting
  - Golf

Calculating the Velocities of the lower limb revealed acceleration and deceleration patterns in a unique sequence



Observing the upper extremities reveals a pattern as well.




CBA Graphing module
Time
.00
430
340
112
468
1012
1705
1854
203
△ = VEL_MAG_L.WRIST
▽ = VEL_MAG_L.ELBOW
□ = VEL_MAG_L.SHOULD
◇ = VEL_MAG_R.SHOULD
◇ = VEL_MAG_R.ELBOW
⧖ = VEL_MAG_R.WRIST
△ = VEL_MAG_R.HAND
▽ = VEL_MAG_C.G.
Cm/S
2000
1500
1000
500
-1.4
-1.2
-1.0
-.8
-.6
-.4
-.2
0.0
Sec

Enter Root Filename [8 Chars]

Filename: dub2vel

Enter-Select

CBA Graphing module

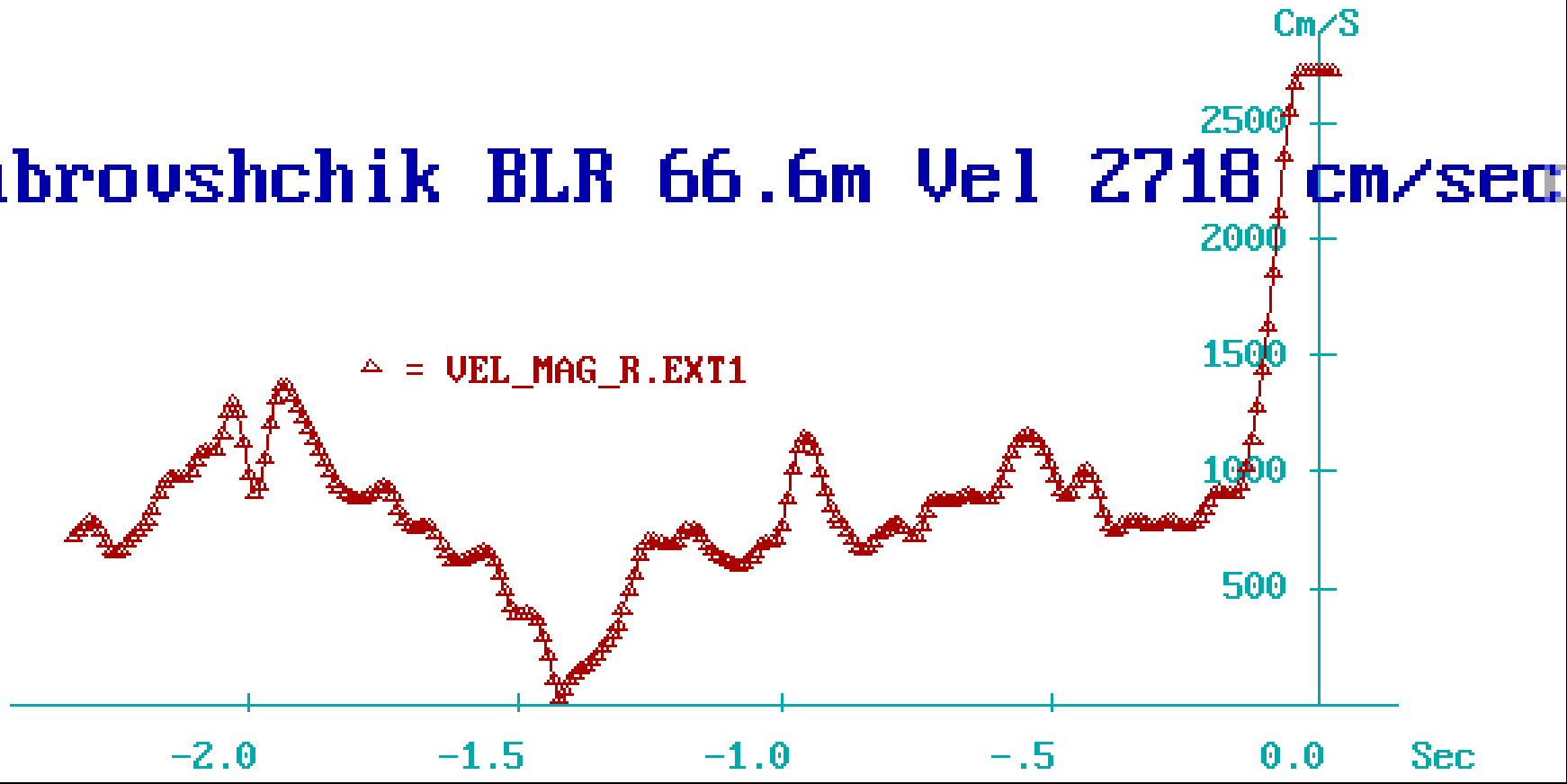
Time

-.003

△

2718.419

Dubrovshchik BLR 66.6m Vel 2718 cm/sec



File Exists

Replace Keep

F10-Quit

CBA Graphing module

Time

-.046

△

2126.684

2484.85

Cm/S

△ = VEL_MAG_R.EXT1

Washington 65.42m

2500

2000

1500

1000

500

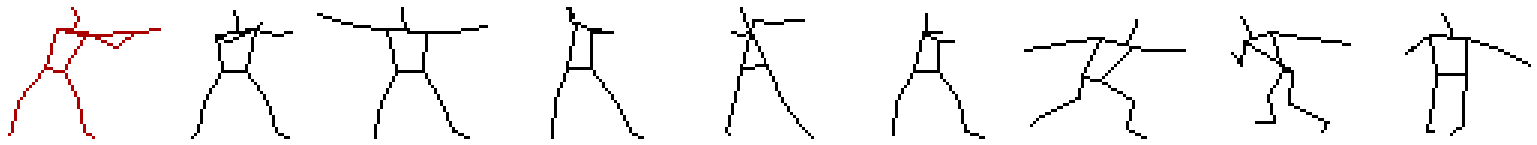
-1.8 -1.6 -1.4 -1.2 -1.0 -.8 -.6 -.4 -.2 0.0 Sec

Enter Root Filename [8 Chars]

Filename: r_momnt

Enter-Select

CBA Graphing module



Time	△	▽
-3.083	144.331	241.038

△ = DISP_X_CG

▽ = DISP_X_R.HAND

Cm

250

200

150

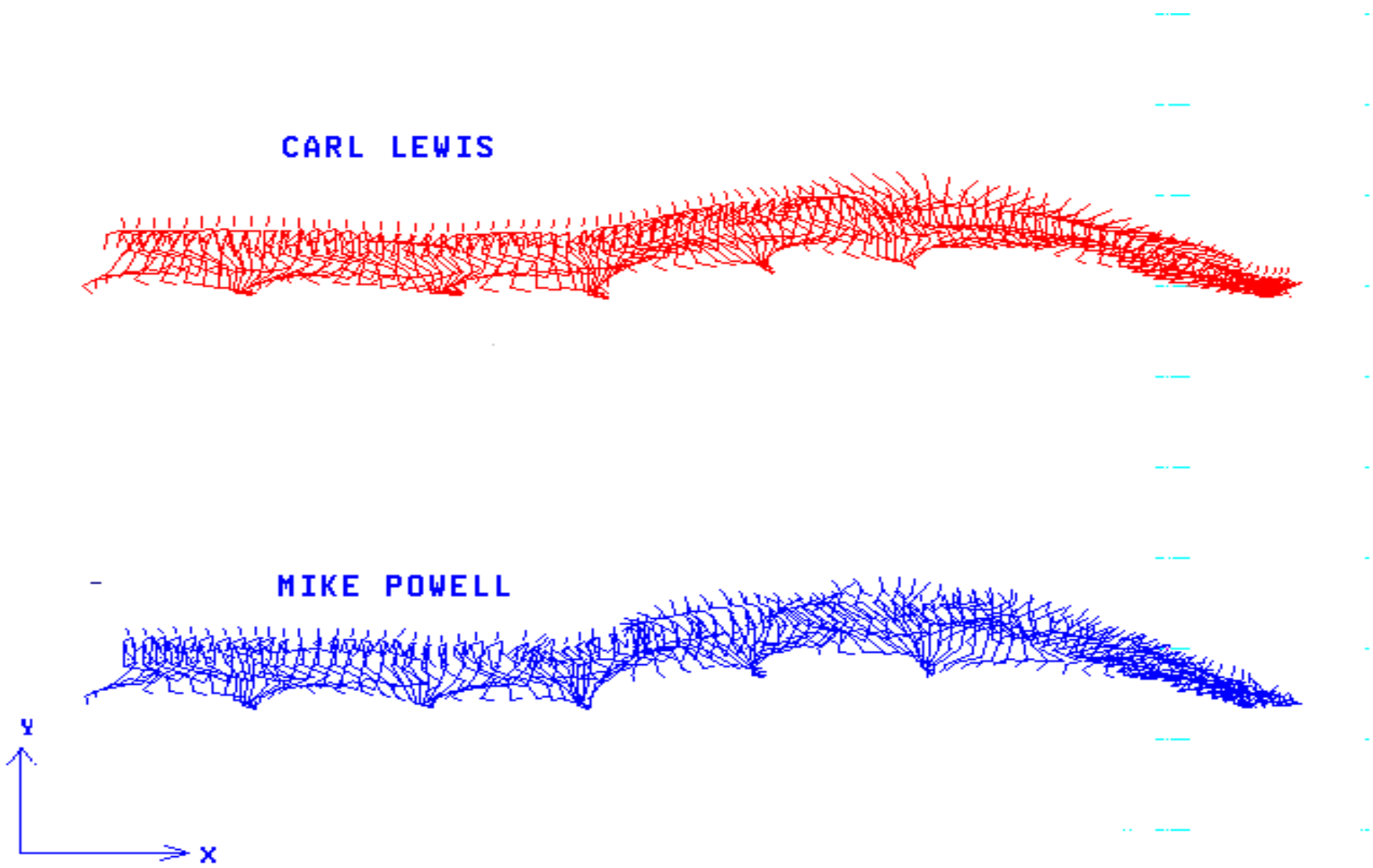
100

50

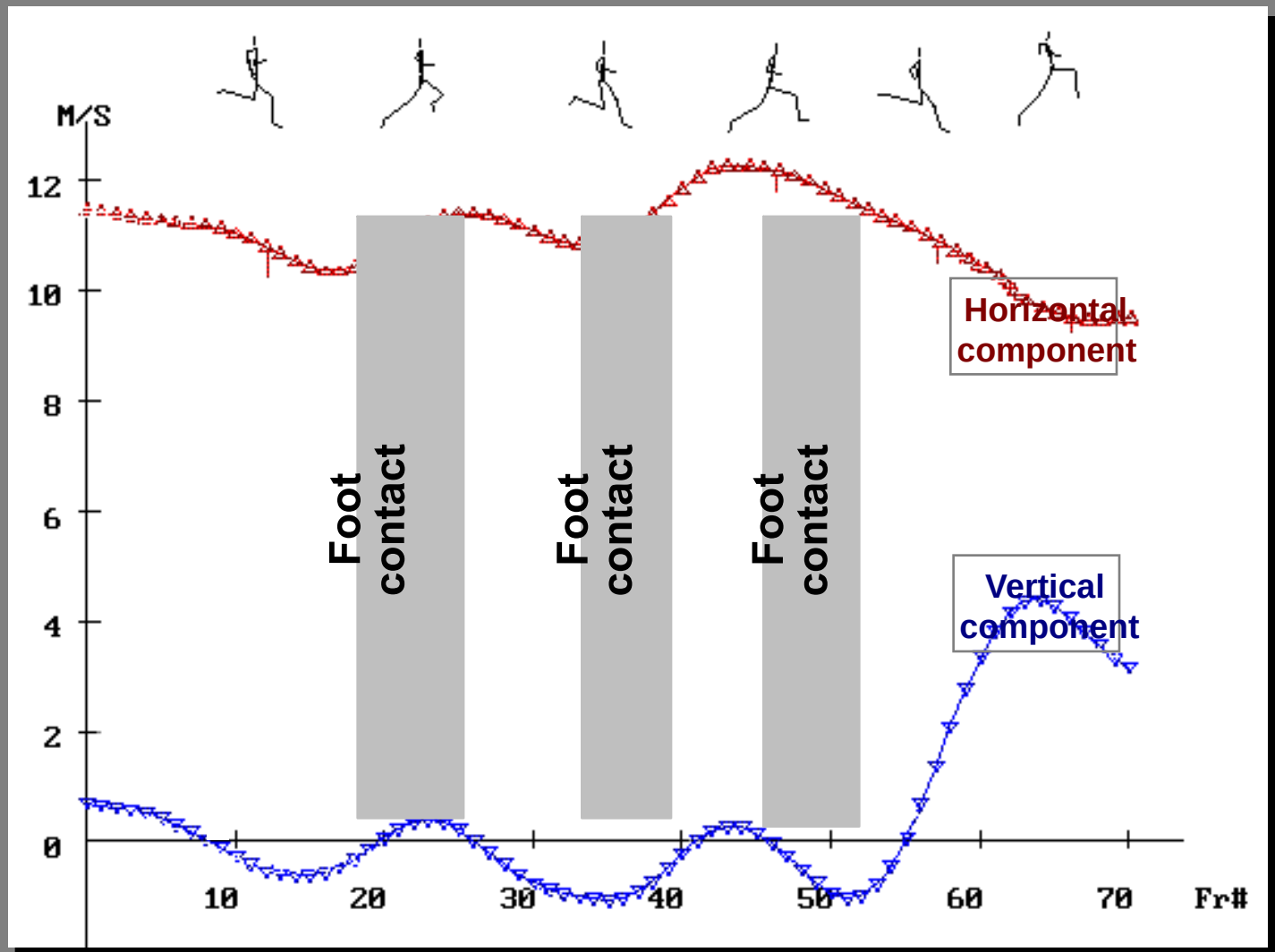
108.80

-3.0 -2.5 -2.0 -1.5 -1.0 -.5 0.0 Sec

THE CASE OF THE LONG JUMP:

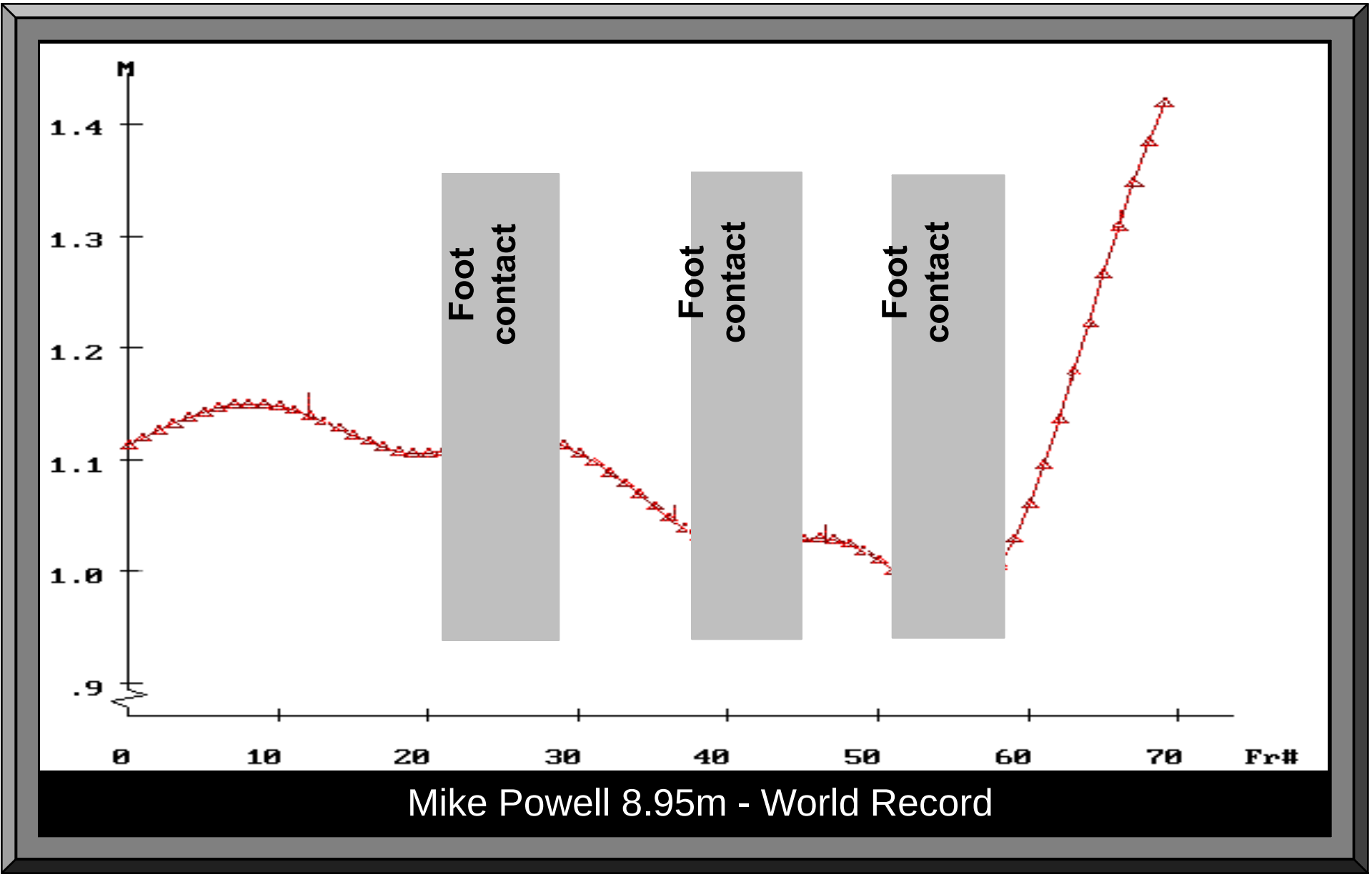


Velocity of the Center of Mass



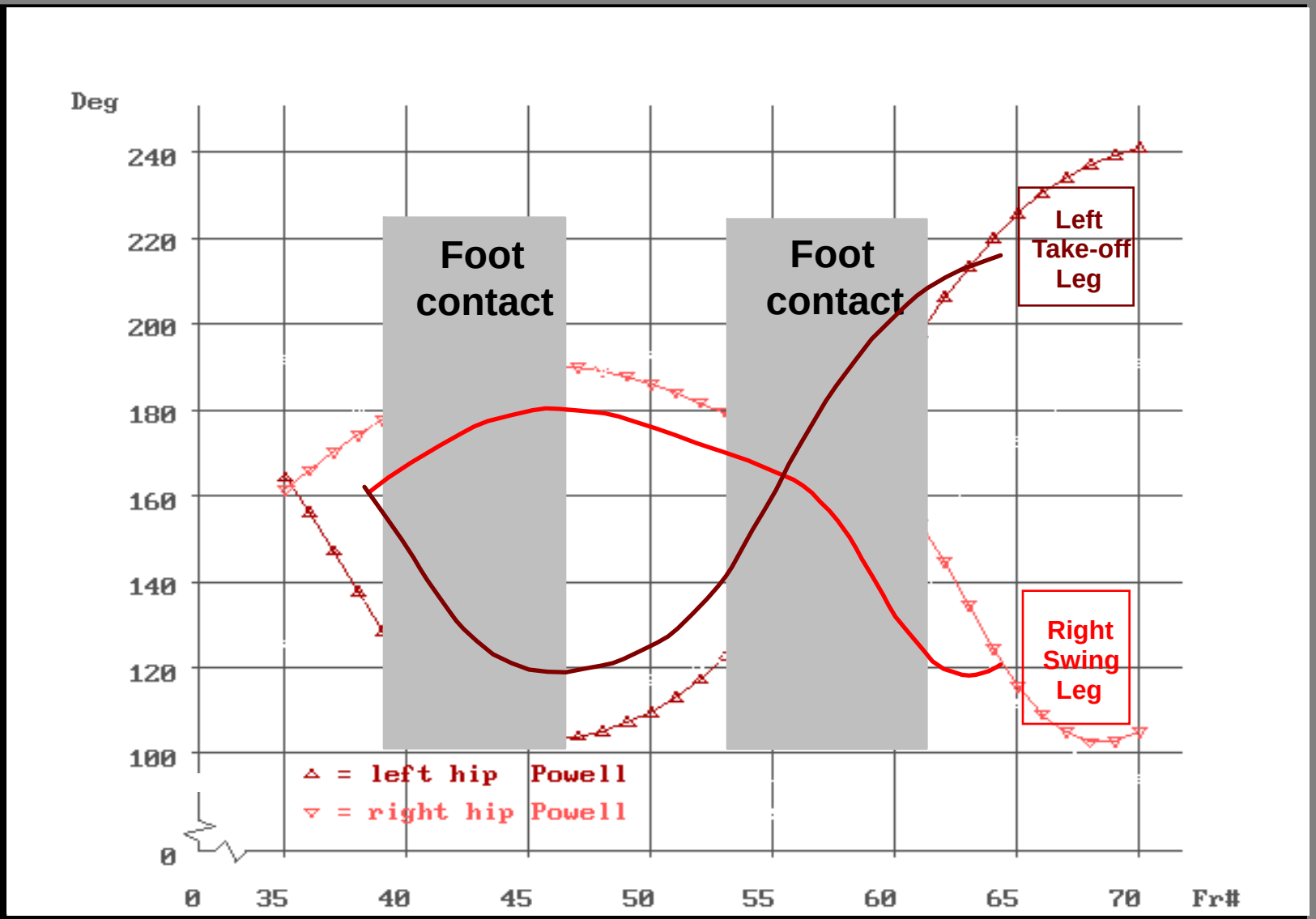
Mike Powell 8.95m - World Record

Height of the Center of Mass



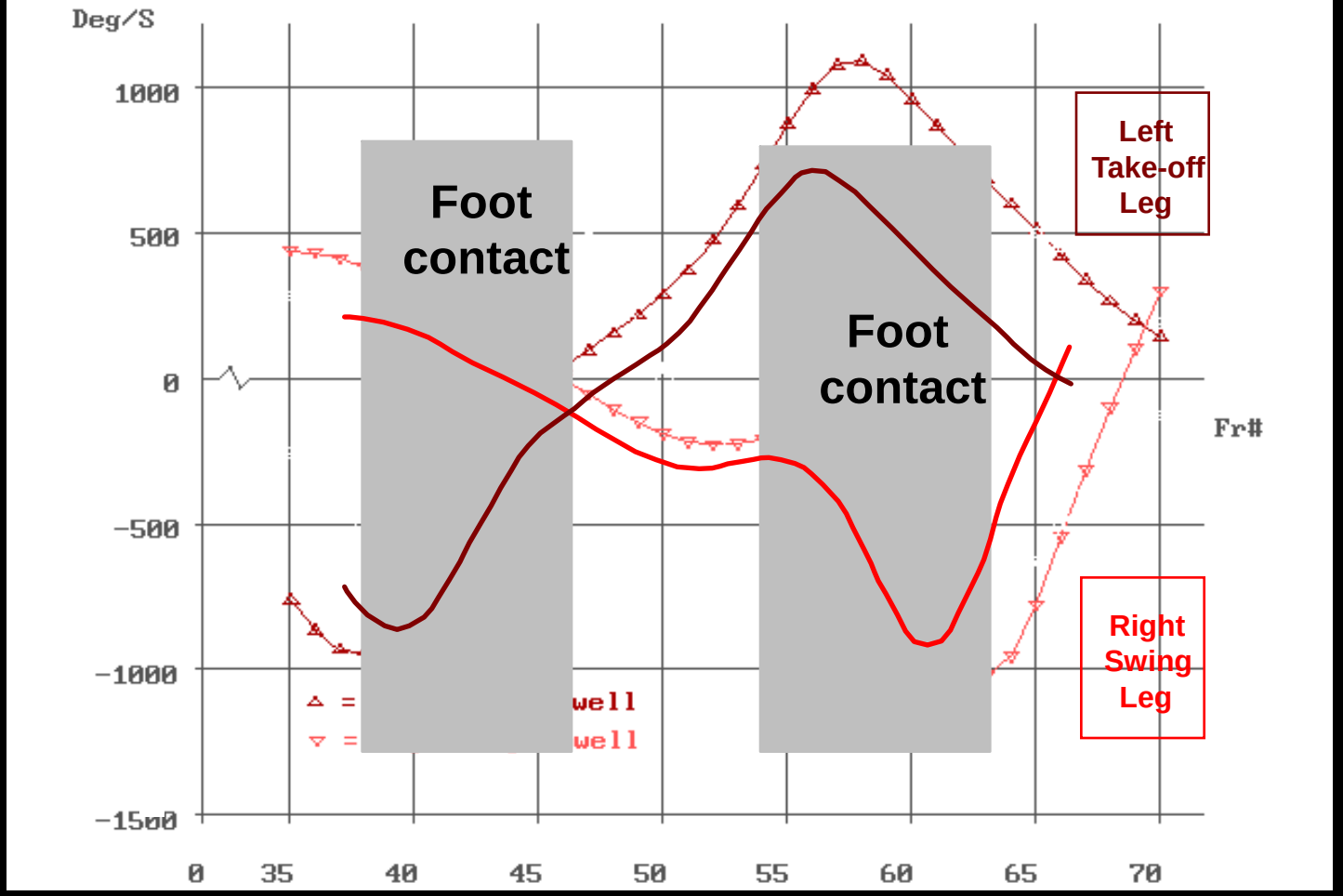
Mike Powell 8.95m - World Record

Angular Displacement in Hip Joints



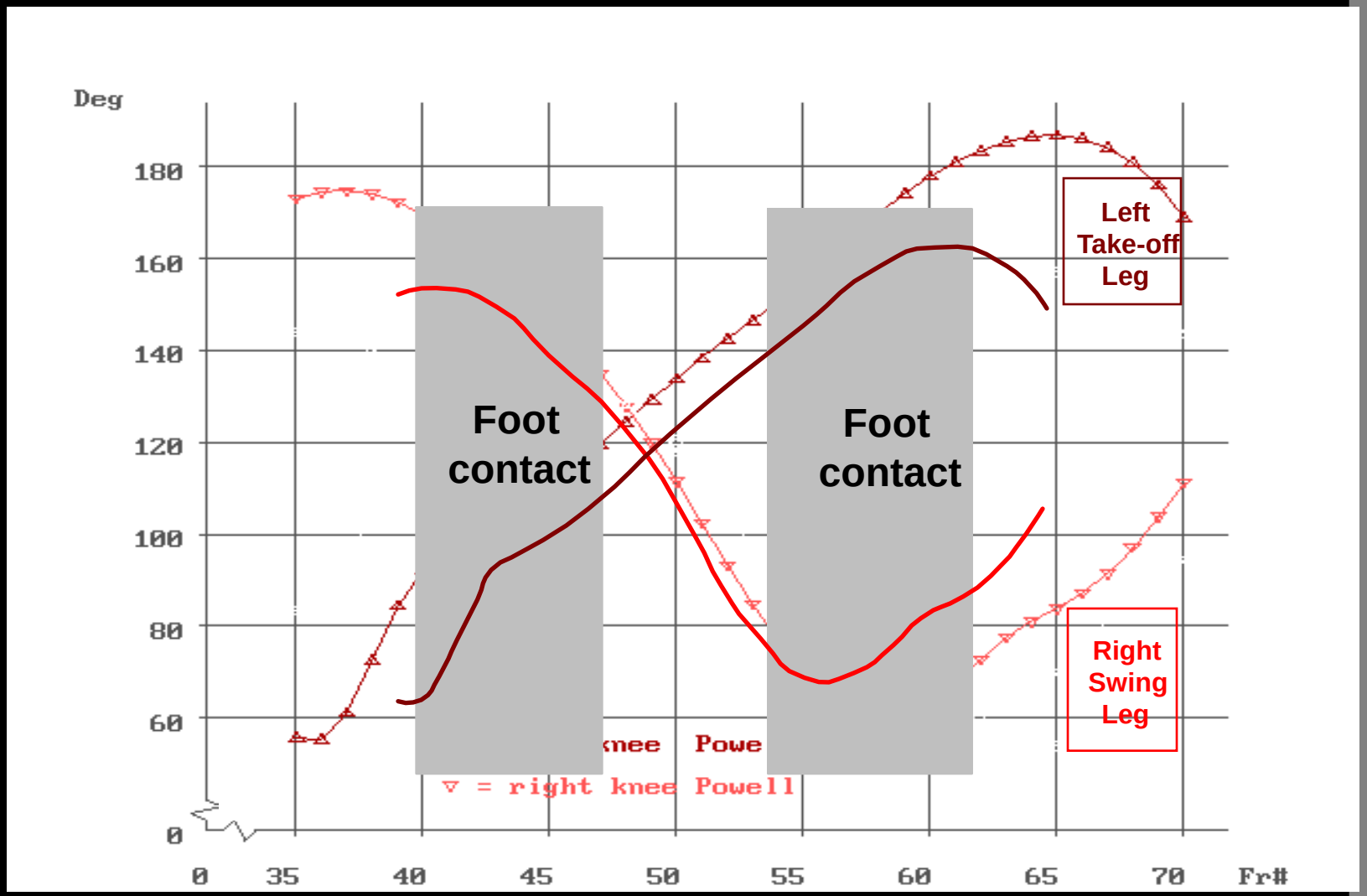
Mike Powell 8.95m - World Record

Angular Velocity in Hip Joints



Mike Powell 8.95m - World Record

Angular Displacement in Knee Joints



Mike Powell 8.95m - World Record

The Internet has opened a new frontier for research and international cooperation on multifaceted studies.

Essentially, in Internet terms, the entire process consists of the following steps:

- Analog video data is captured off-site and off-line through the use of a frame-by-frame advance VCR.
- Analog video data is converted off-site and off-line to digital video data in AVI format.
- Digital video data in AVI format is transmitted via FTP from a remote PC (browser) to a web server.

- **The web server, converts the AVI frames into individual GIF files.**
- **The web server, through CGI, super-imposes the x,y,z coordinates on the video images.**
- **The web server sends back the processed (digitized) image frames back to the remote PC (browser) with all pertinent mathematical and physical observations, analysis, and conclusions.**

Utilizing the tools available in Cyberspace, the Biomechanist, The Coach and the Sport Scientist can retrieve and display data as well as documents from virtually anywhere on the planet. Studies can be conducted at multiple locations and data rapidly exchanged among these sites.

The Cyber Coach

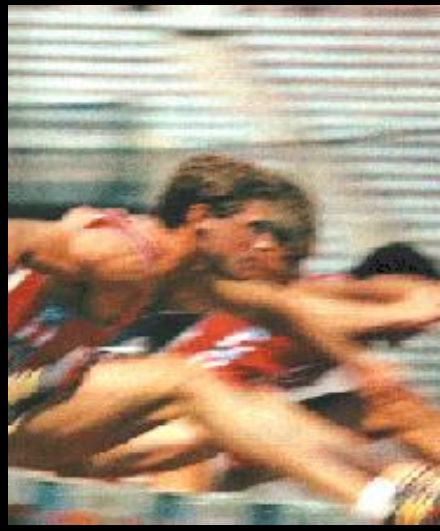
Hammer1.avi

200 m
19.32
USA
2370
MIKE BLAKE/REUTTERS

3478
3298
Ross Kinnaird/Allsport

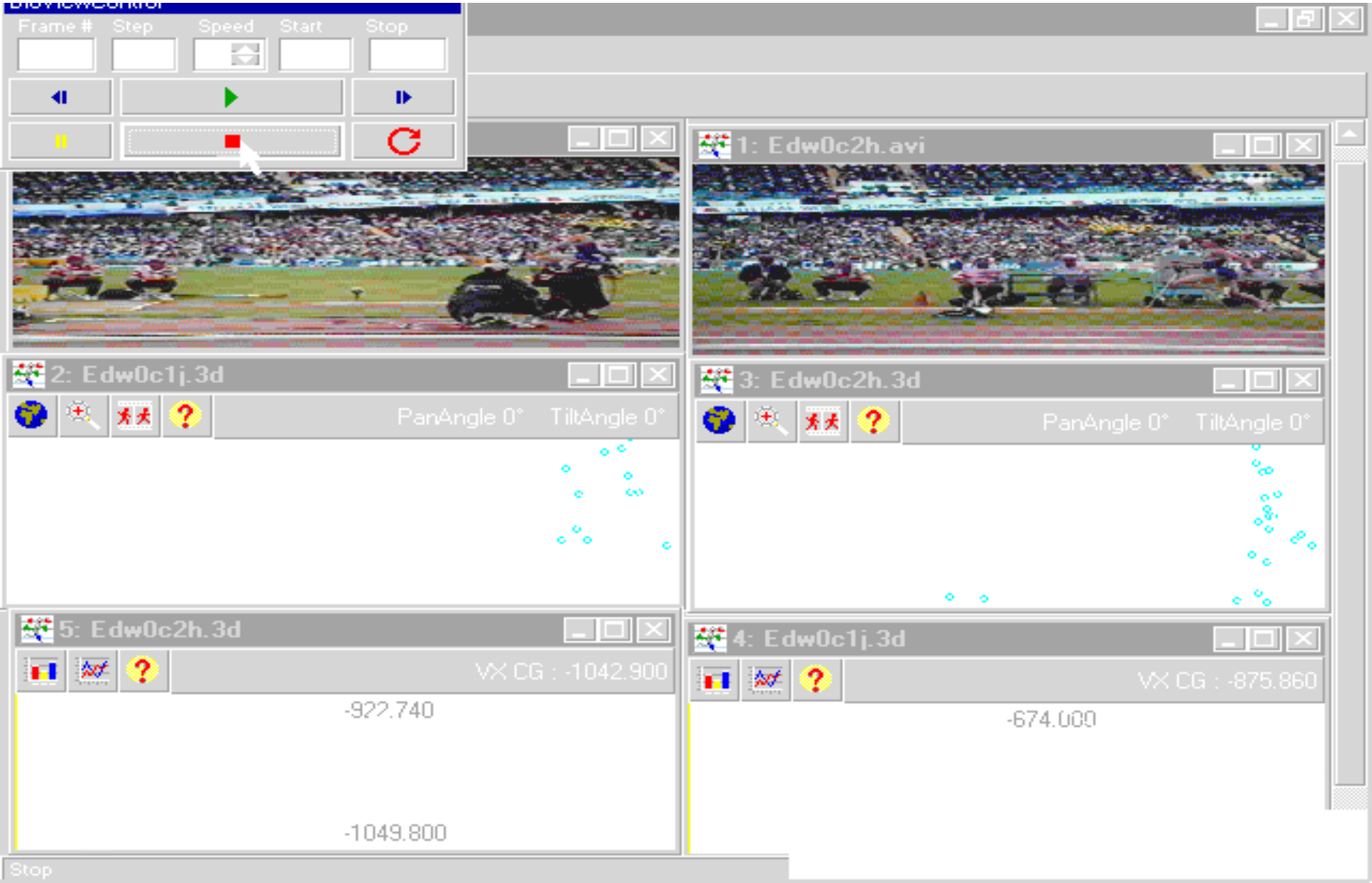
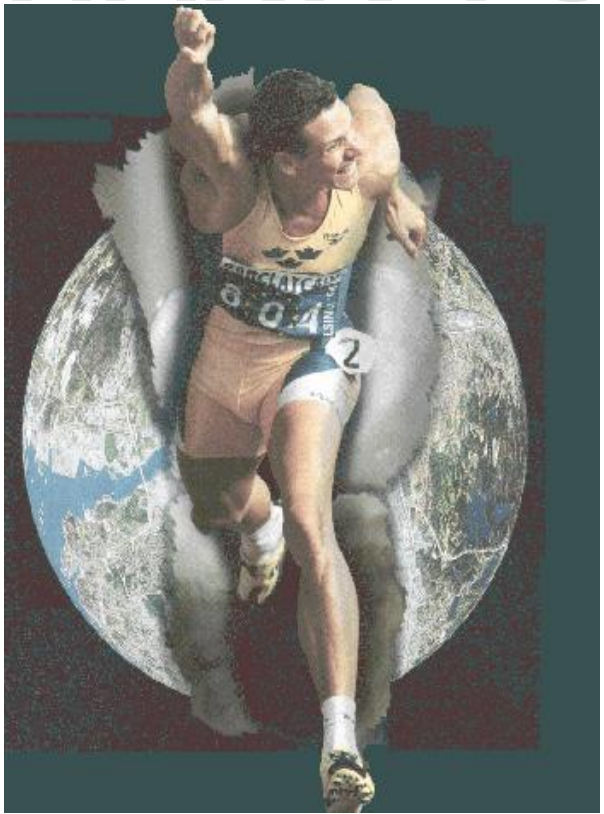
run1.avi

Hurdle1.avi



PV1.avi

Bioview


Frame #
Step
Speed
Start
Stop
1: Edw0c2h.avi
2: Edw0c1j.3d
PanAngle 0°
TiltAngle 0°
3: Edw0c2h.3d
PanAngle 0°
TiltAngle 0°
5: Edw0c2h.3d
VX CG : -1042.900
-922.740
-1049.800
4: Edw0c1j.3d
VX CG : -875.860
-674.000
Stop

THANK YOU