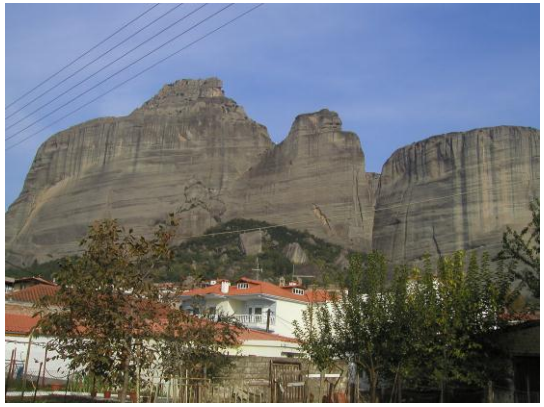
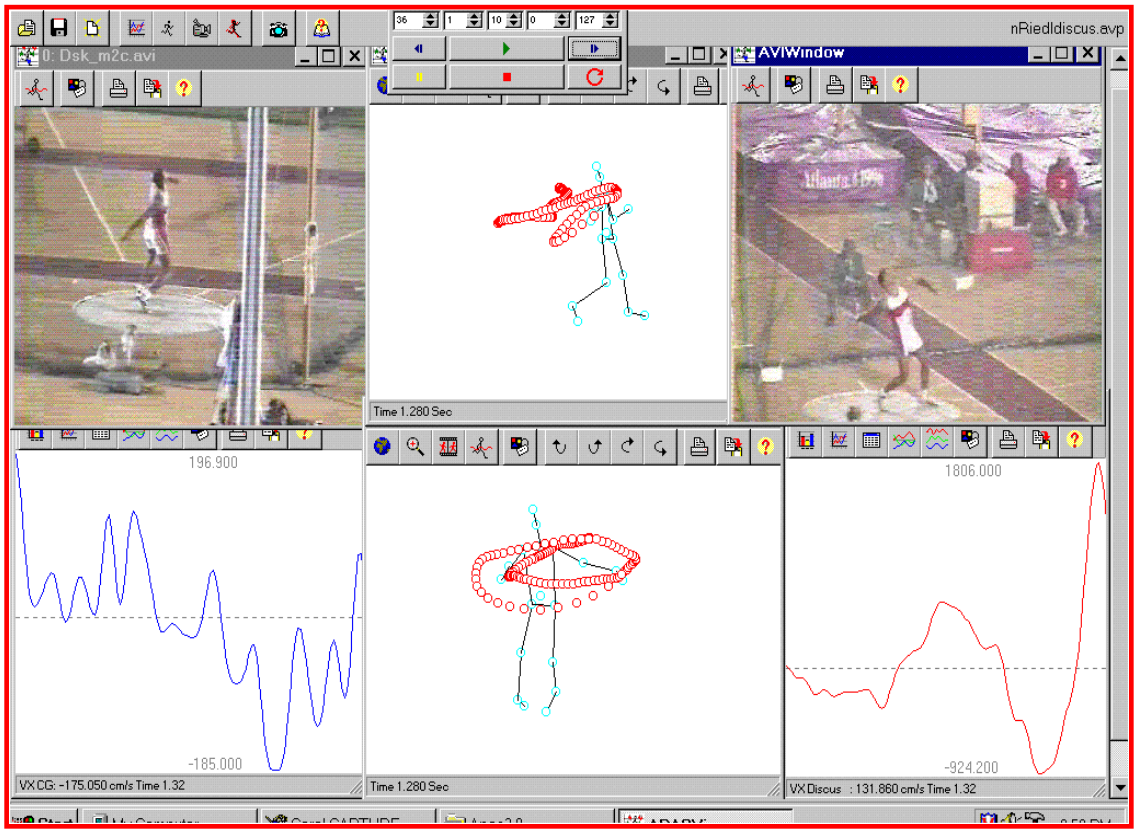
Optimizing Athletic Performance Through High-tech

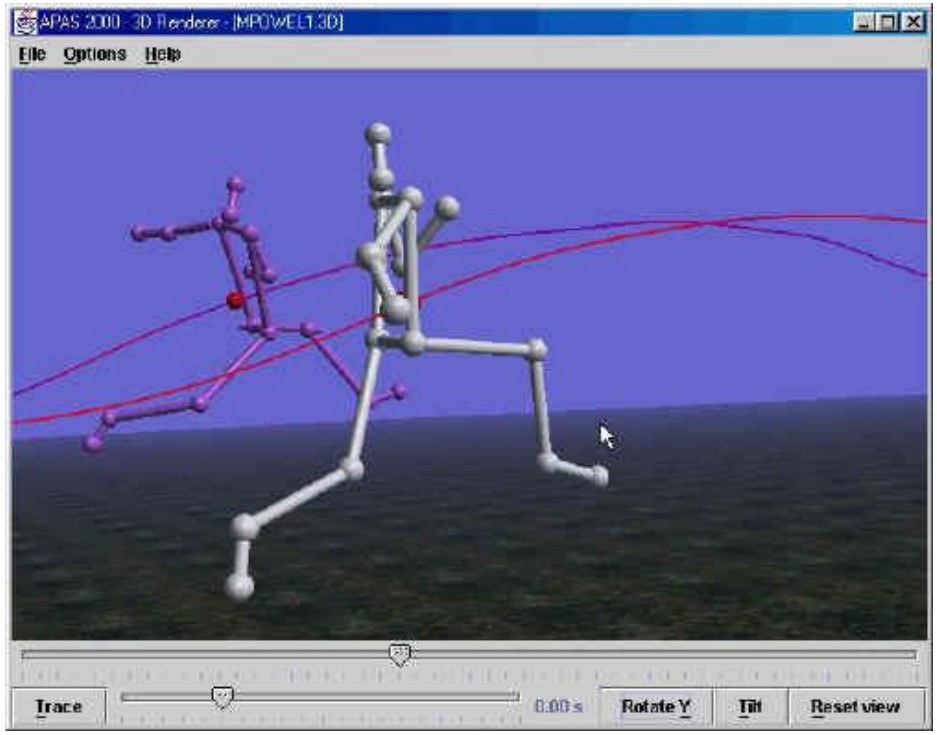




By Gideon Ariel, Ph.D.

Trikala Greece November, 1st 2002

MOVEMENT ANALYSIS CAN BE APPLIED TO:

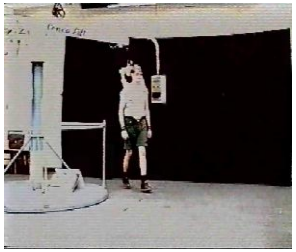


Athletics

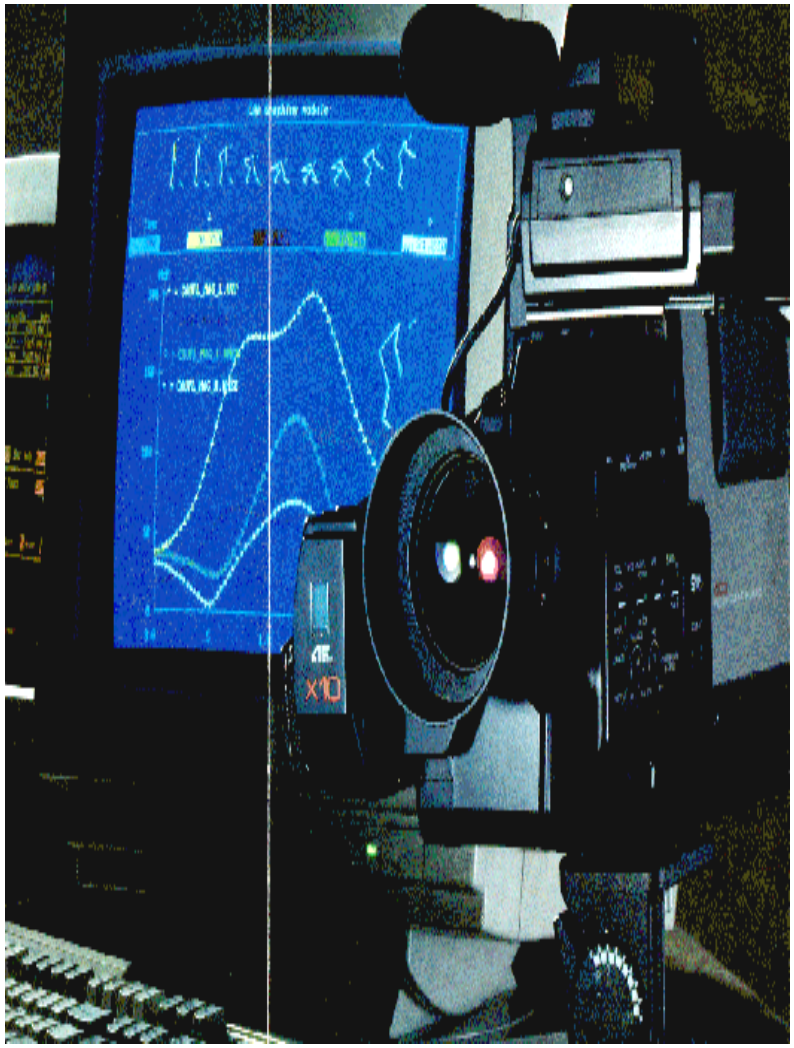
Industry

Medicine

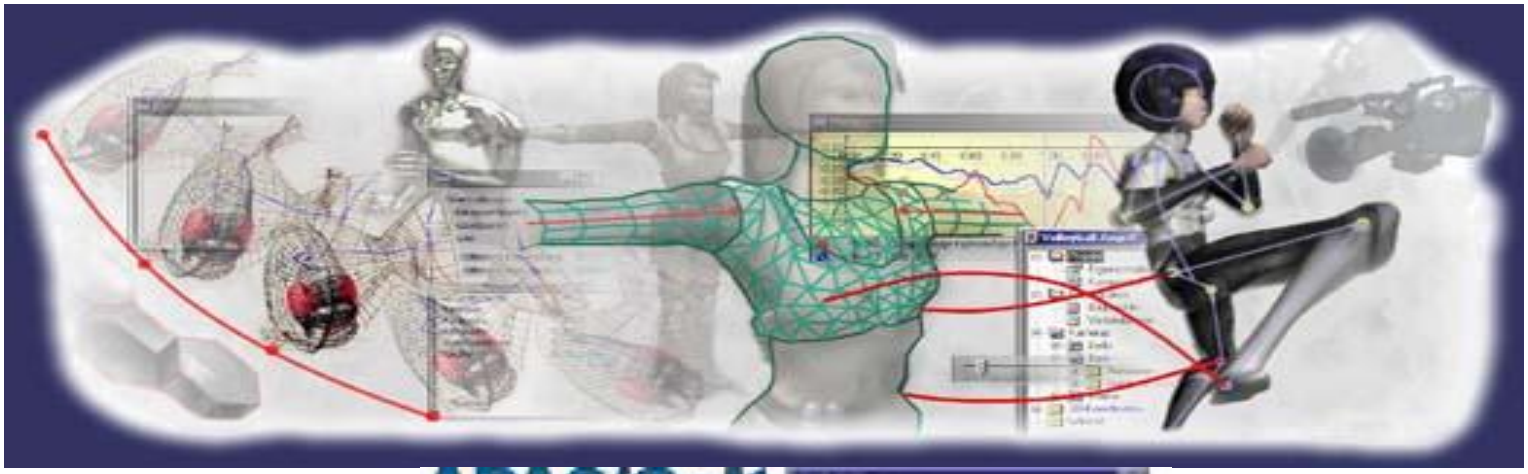
Space



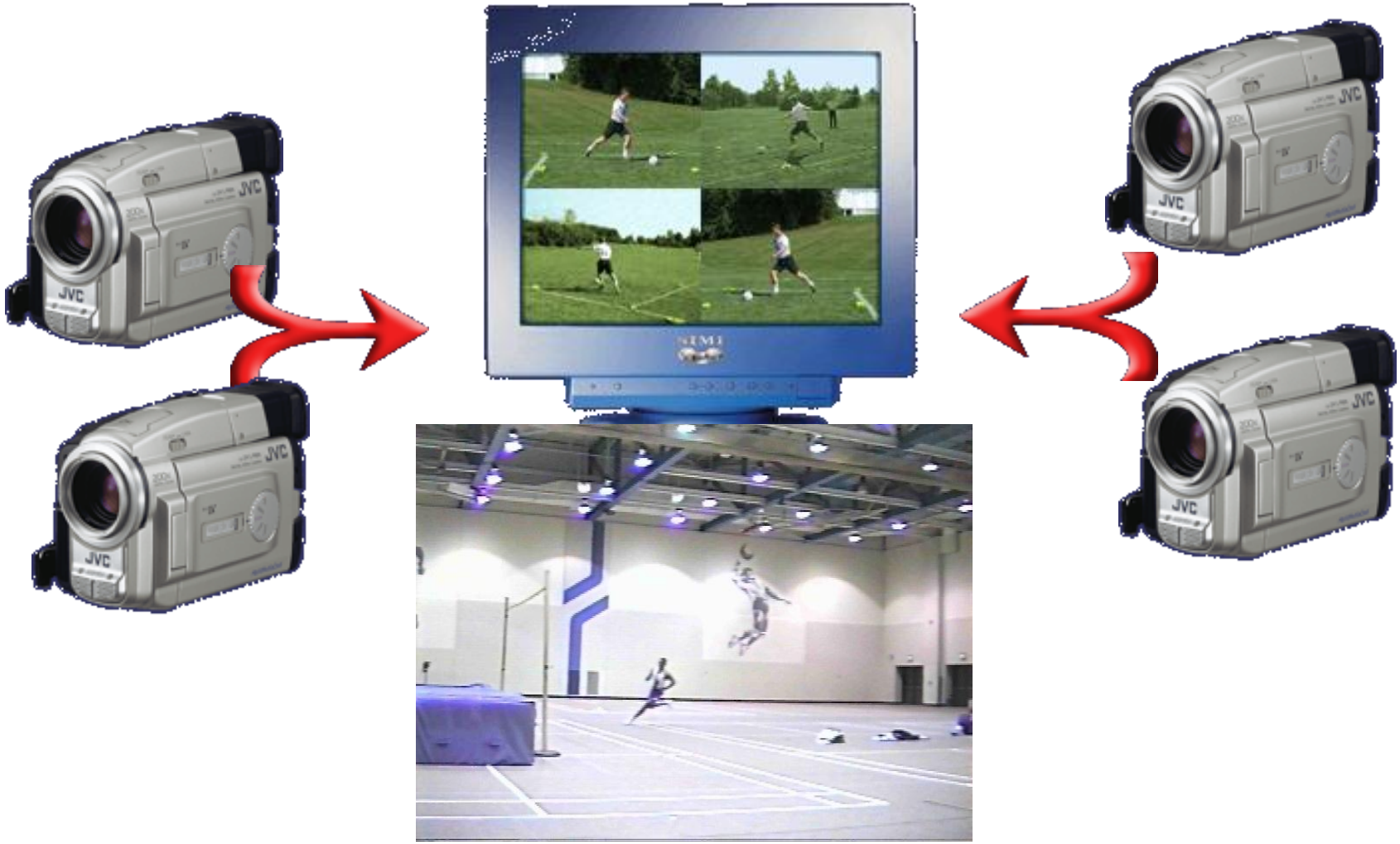
ALL APPLICATIONS UTILIZED SIMILAR QUANTIFICATION TECHNIQUES



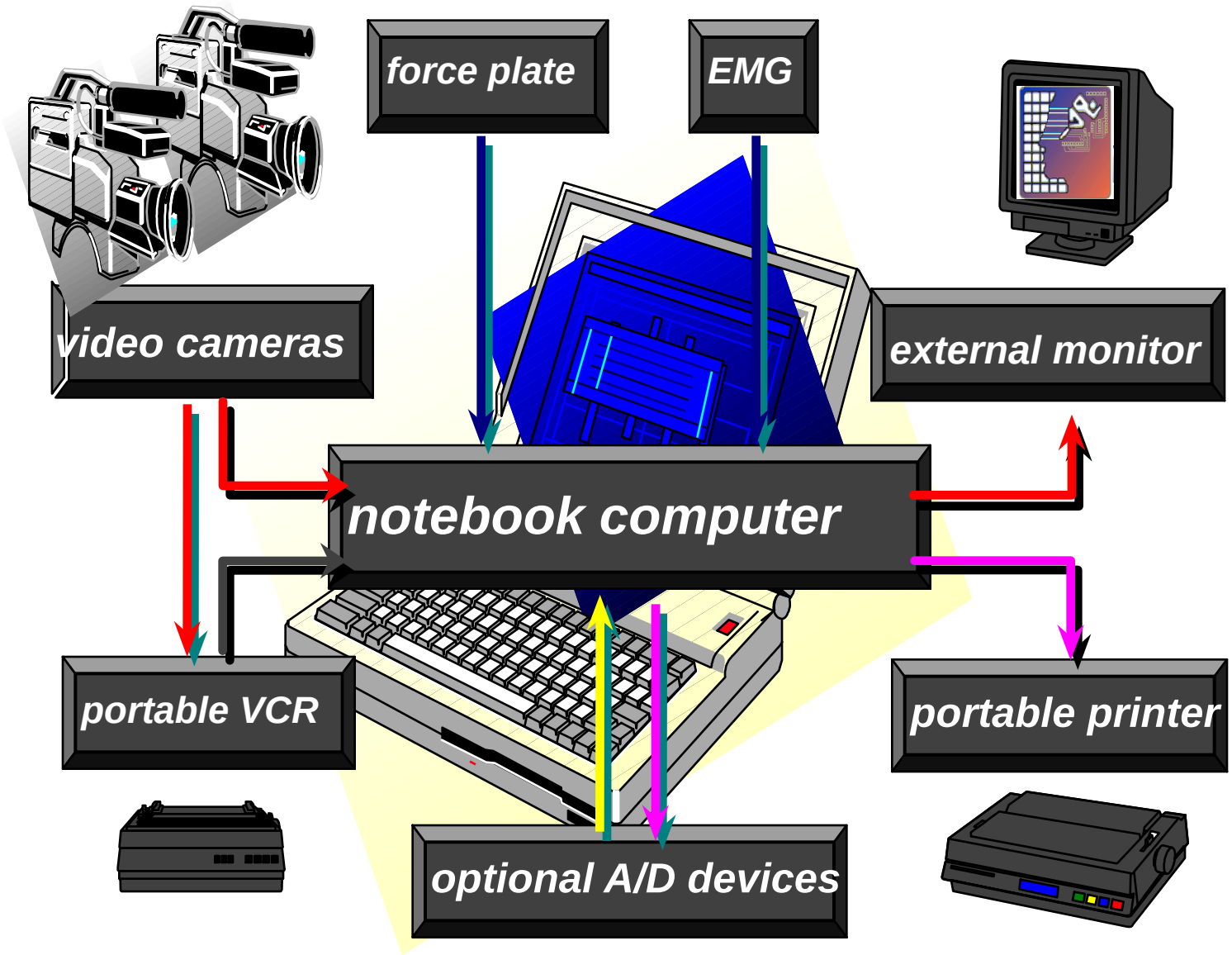
Captures Movement in Three-Dimensional Space



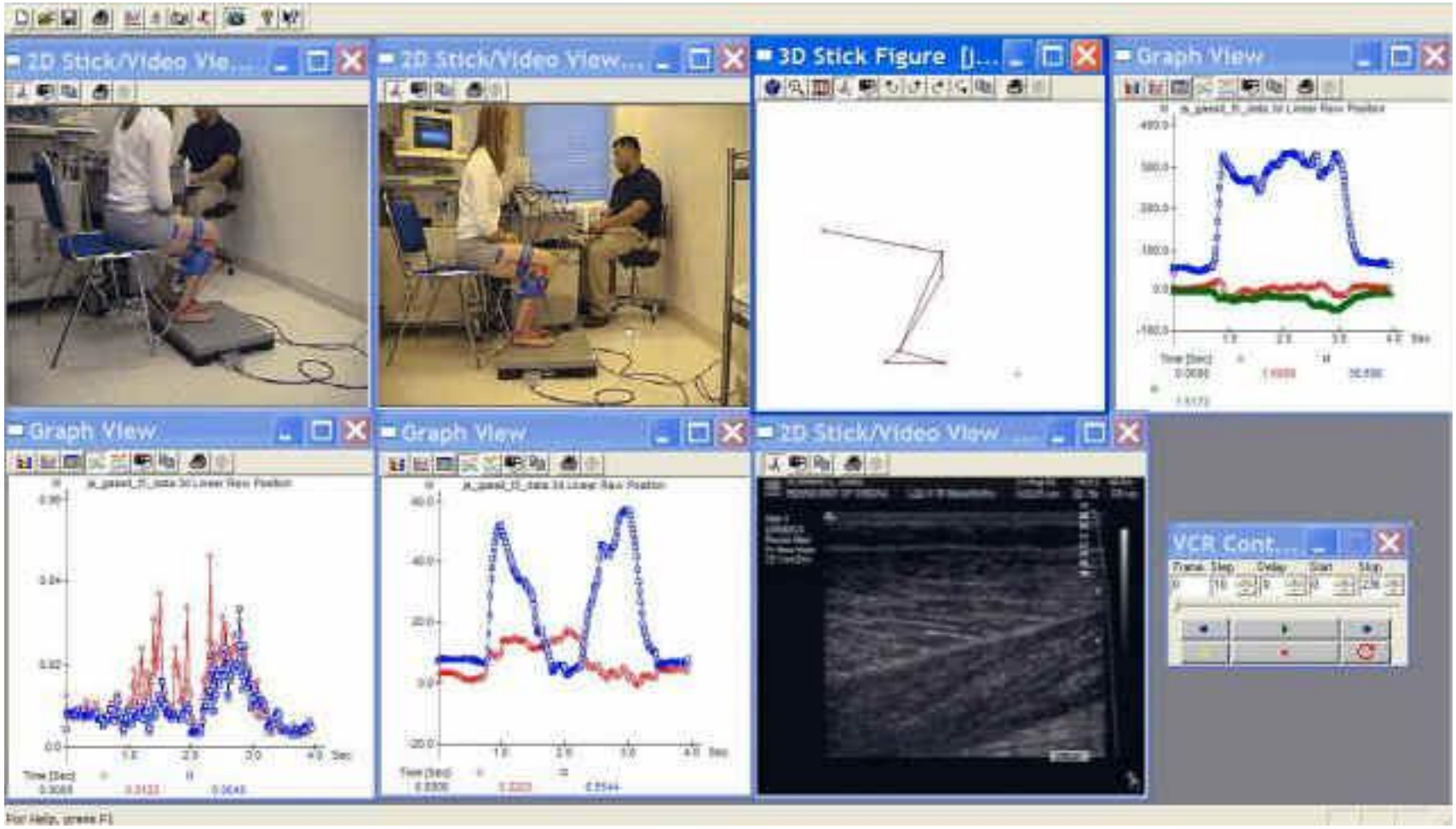
Capture videos using several cameras simultaneously and save the clips directly as AVI files to your hard disk. This allows you to connect multiple digital video cameras to your computer and to start capturing with one mouse click.



Basic Components of Motion Analysis System



In the Laboratory



The Spectrum of Athletic Performances

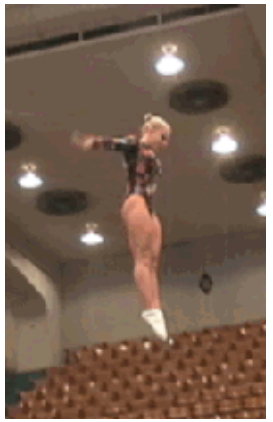
- Explosive events
  - Throwing
  - Sprinting
  - Jumping

- Endurance events
  - Long distance run
  - Swimming
  - Cycling

- Accuracy events
  - Golf
  - Archery

- Team sports
  - Soccer
  - Basketball
  - Hockey

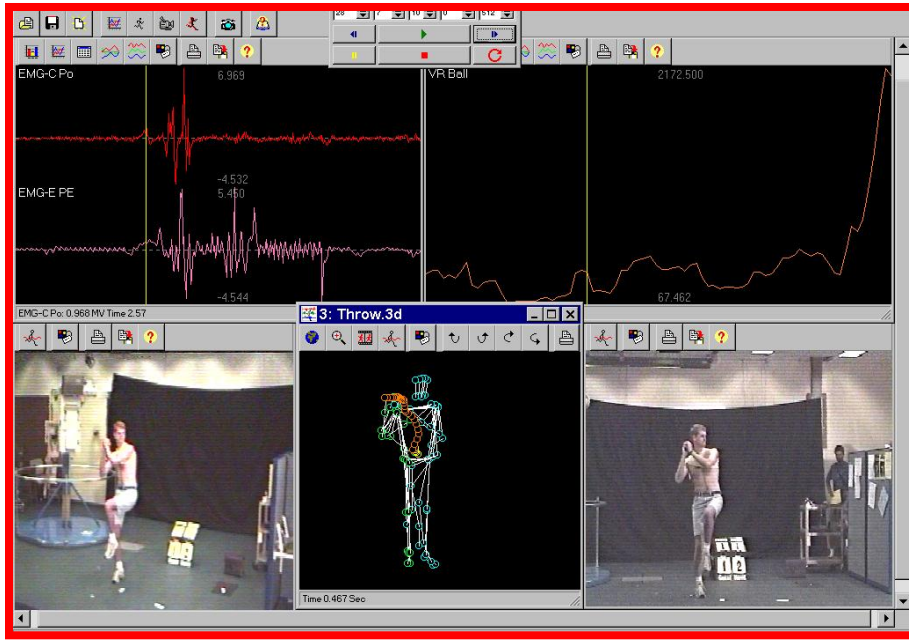
- Esthetic events
  - Figure skating
  - Gymnastics
  - Diving



- Multi events
  - Decathlon
  - Pentathlon

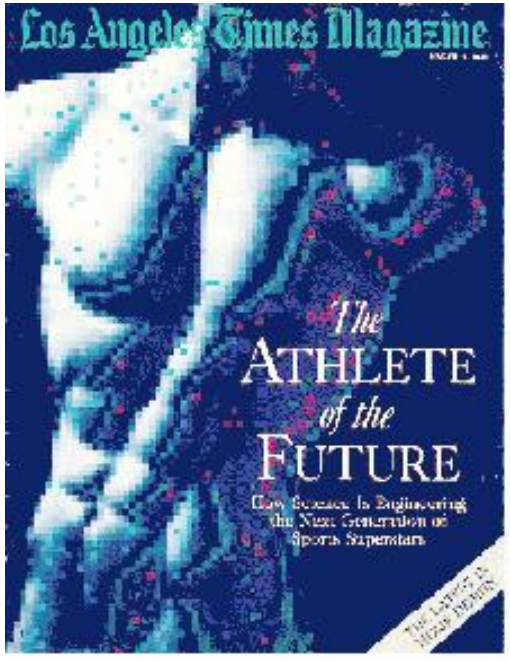
Hardware

- Main Computer System
- Workstations
- High Speed Camera
- Capture Card
- Network
  - Intranet
  - Internet



Analysis of Performance Requires:

- Video Recording
- Digitizing the Data
  - Manual
  - Automatic
- Transformation of the Data
  - 2D - Two Dimensional
  - 3D - Three Dimensional



Video Recording

Camera Views

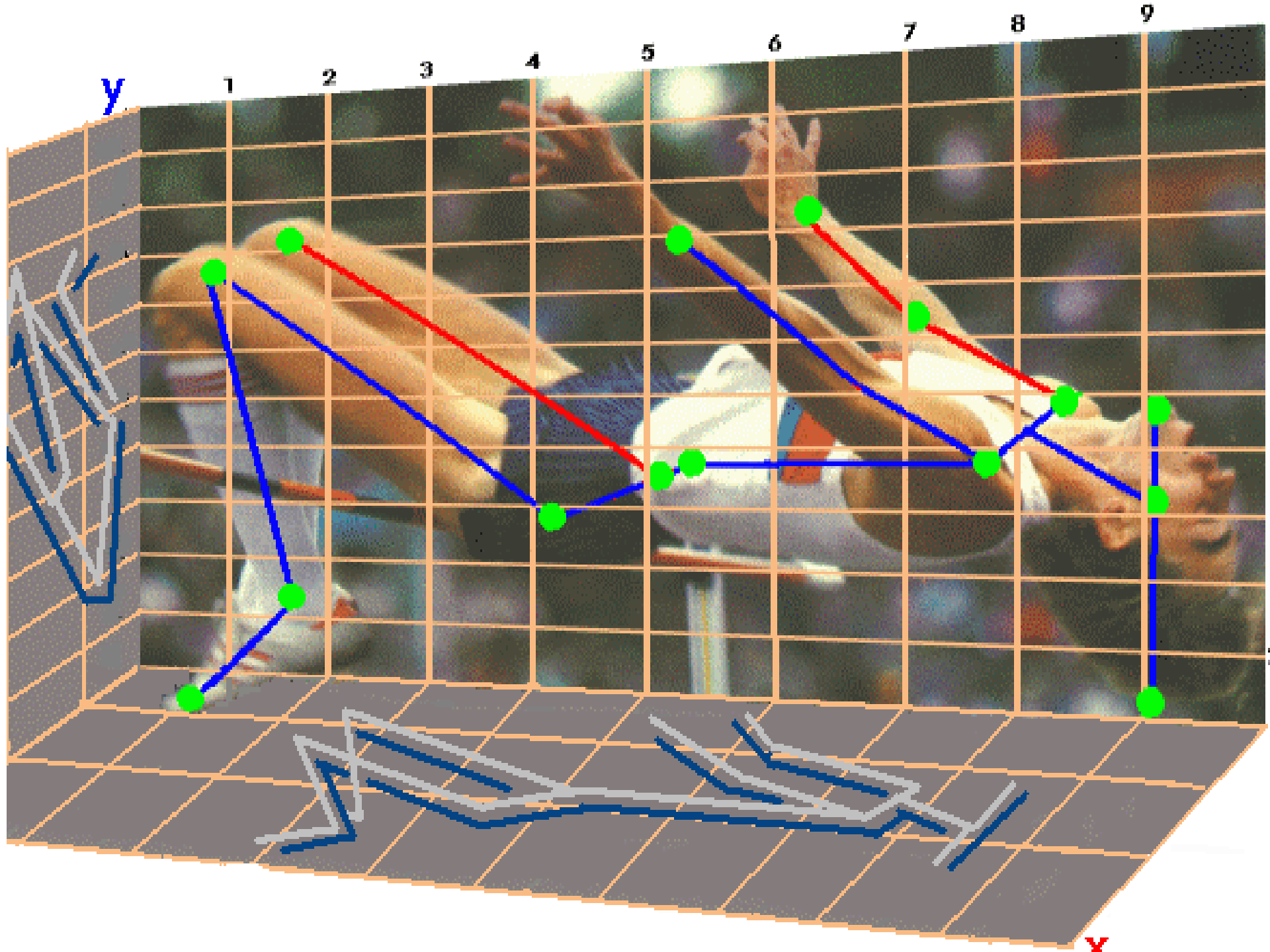

Atlanta 1996

The world record in triple jump of 18.29m by J. Edwards, UK

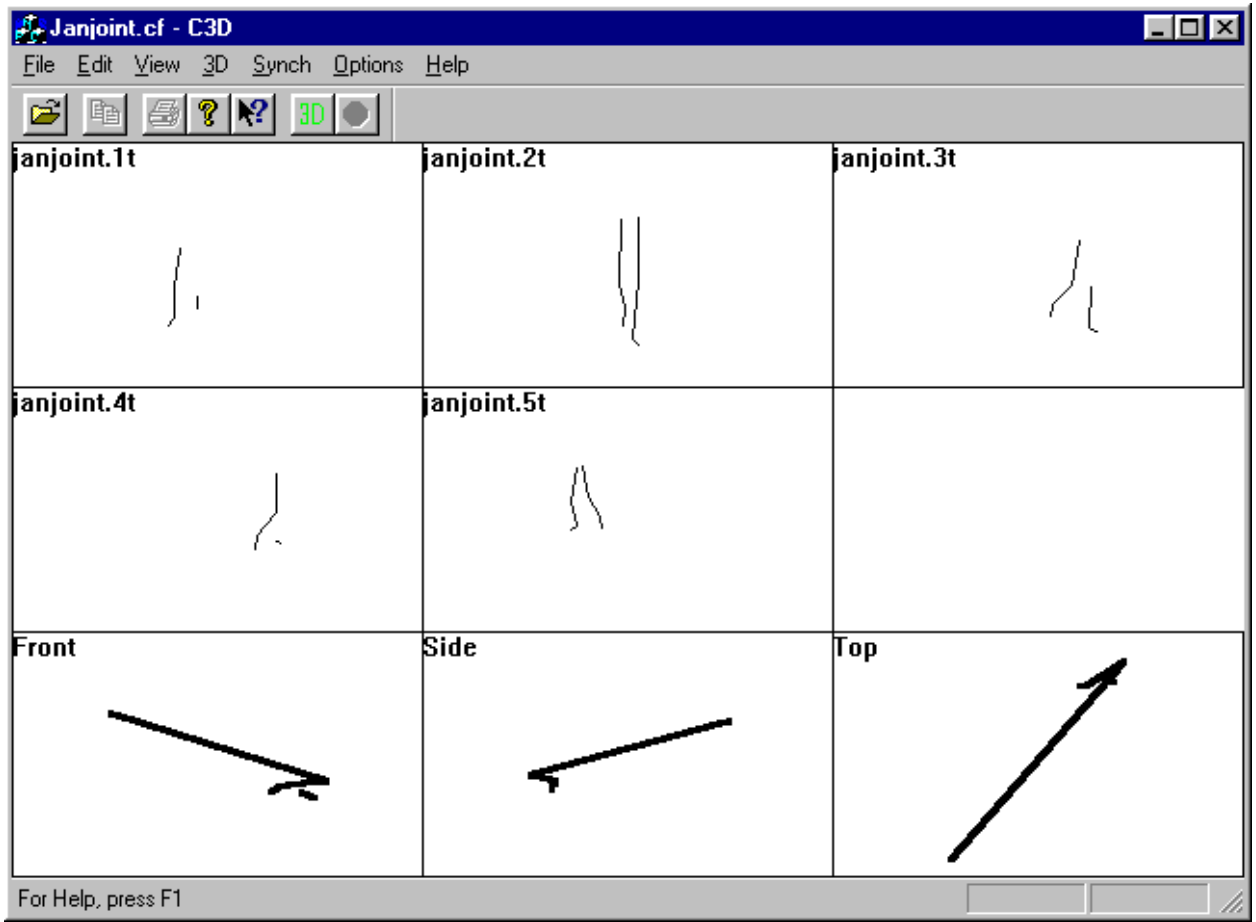
HTML Document

Digitizing

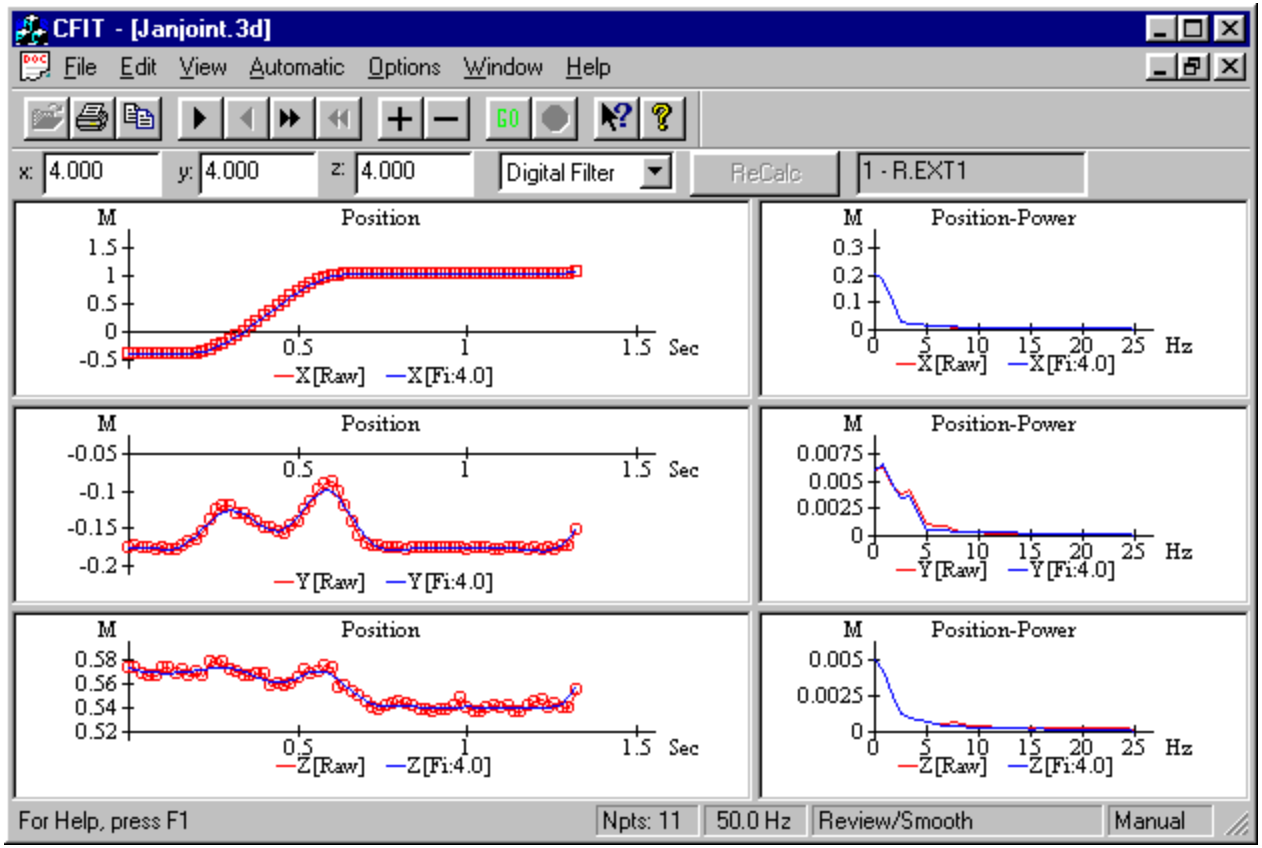
- Manually
- Automatically


y
1
2
3
4
5
6
7
8
9
x

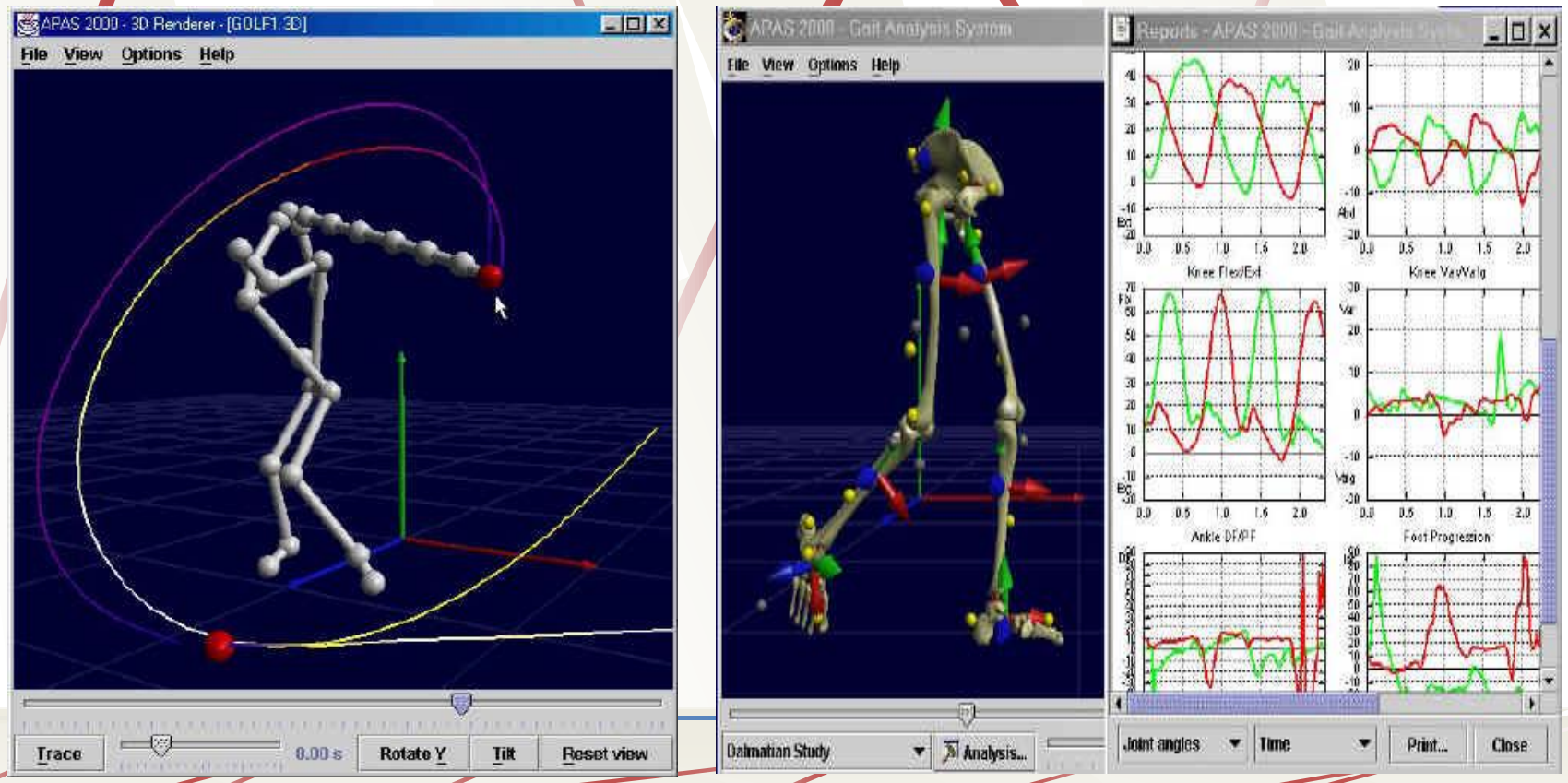
Transformation



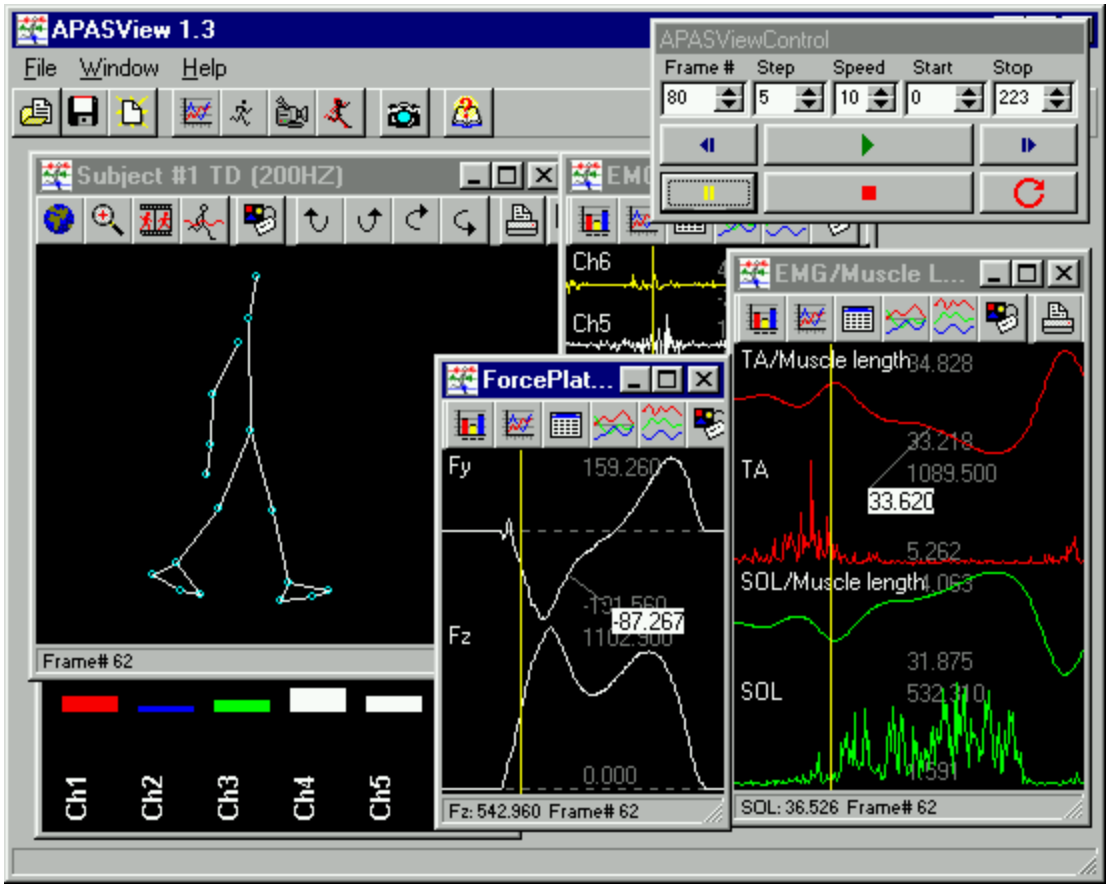
Filtering/smoothing



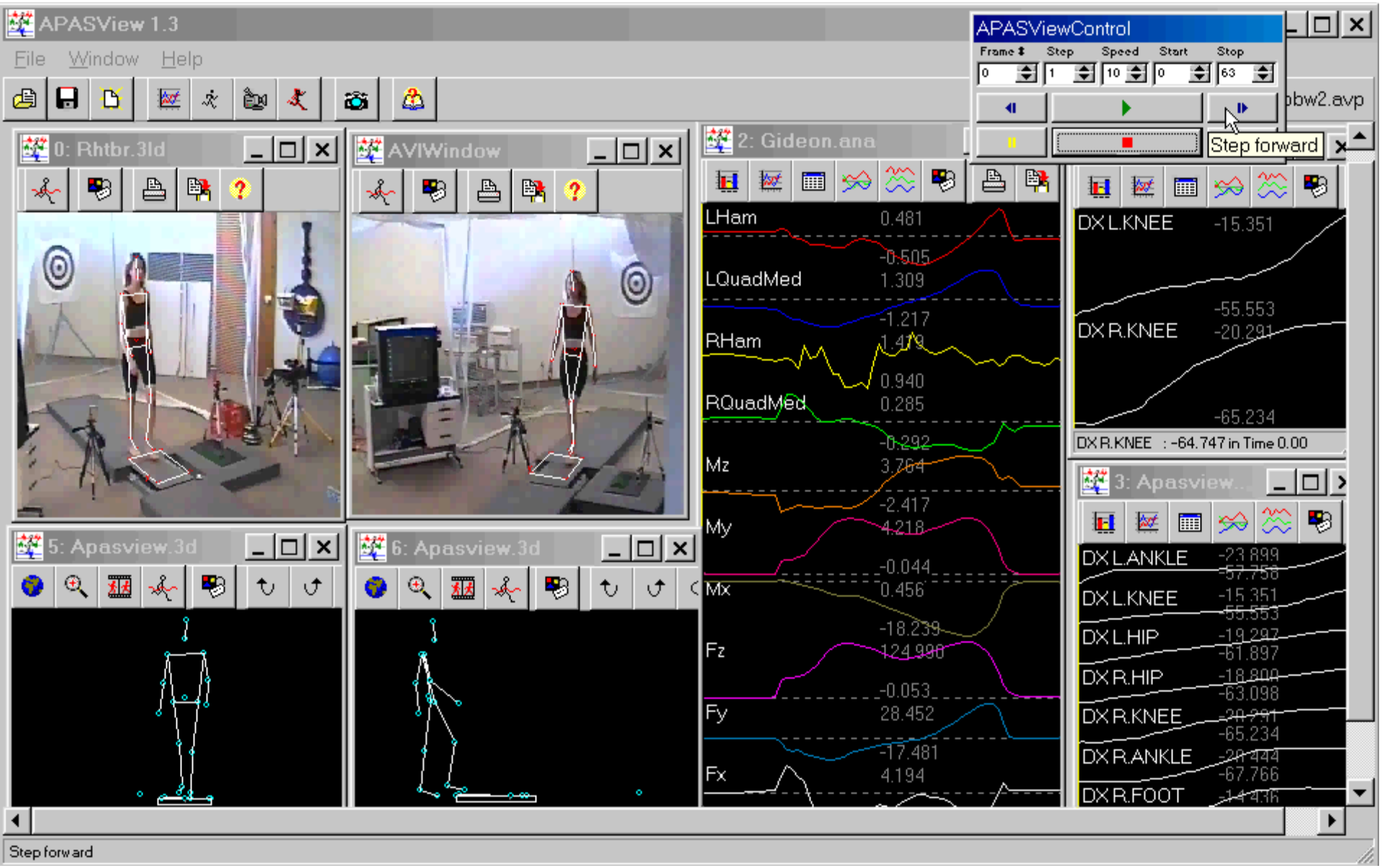
Software Integration



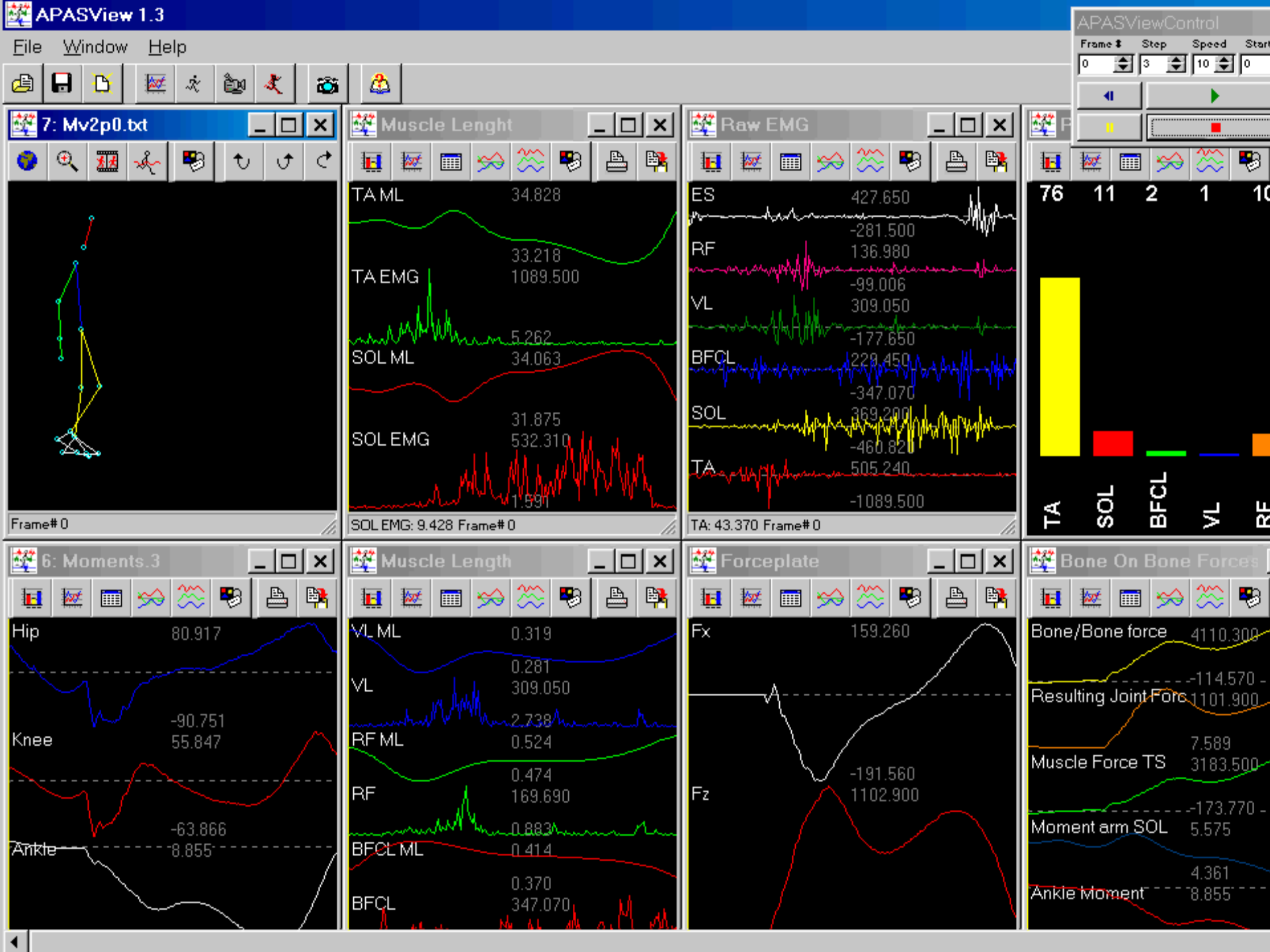
Display and Analysis

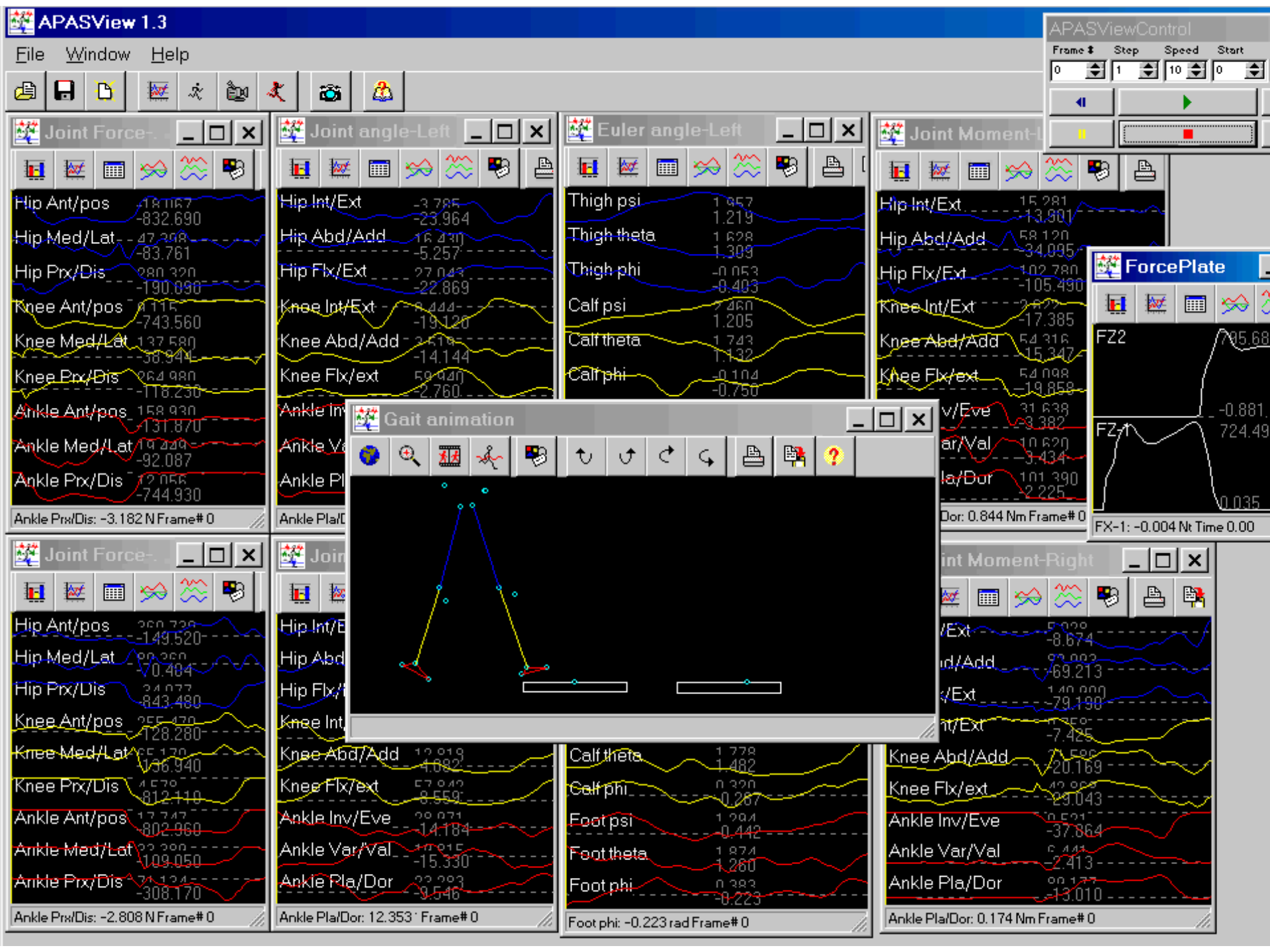


Displaywin.exe



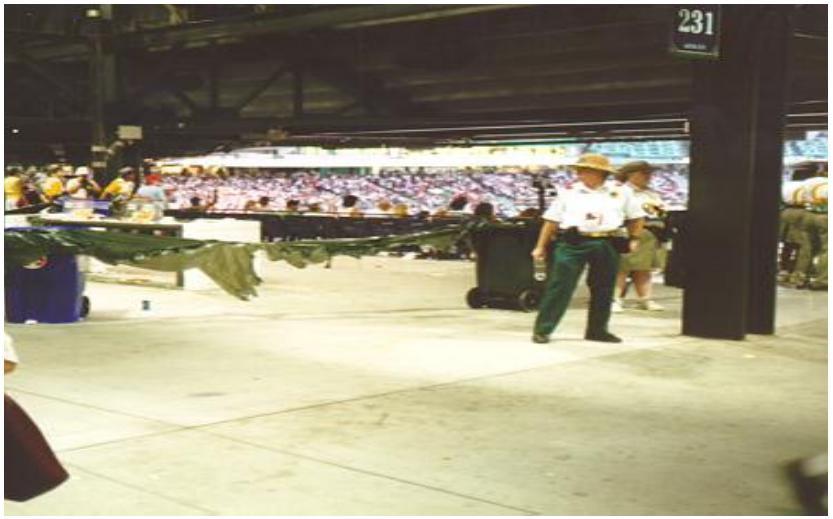
[Software Integration]


APASView 1.3
File
Window
Help
APASViewControl
Frame #
Step
Speed
Start
7: Mv2p0.txt
Frame# 0
Muscle Lenght
TA ML
34.828
33.218
TA EMG
1089.500
5.262
SOL ML
34.063
31.875
SOL EMG
532.310
1.591
SOL EMG: 9.428 Frame# 0
Raw EMG
ES
427.650
-281.500
RF
136.980
-99.006
VL
309.050
-177.650
BFCL
229.450
-347.070
SOL
369.200
-460.820
TA
505.240
-1089.500
TA: 43.370 Frame# 0
76
11
2
1
TA
SOL
BFCL
VL
6: Moments.3
Hip
80.917
-90.751
Knee
55.847
-63.866
Ankle
8.855
Muscle Length
VL ML
0.319
0.281
VL
309.050
2.738
RF ML
0.524
0.474
RF
169.690
0.883
BFCL ML
0.414
0.370
BFCL
347.070
Forceplate
Fx
159.260
-191.560
Fz
1102.900
Bone On Bone Forces
Bone/Bone force
4110.300
-114.570
Resulting Joint Forc
1101.900
7.589
Muscle Force TS
3183.500
-173.770
Moment arm SOL
5.575
4.361
Ankle Moment
8.855


APASView 1.3
File
Window
Help
APASViewControl
Frame #
Step
Speed
Start
Joint Force-
Hip Ant/pos
Hip Med/Lat
Hip Prx/Dis
Knee Ant/pos
Knee Med/Lat
Knee Prx/Dis
Ankle Ant/pos
Ankle Med/Lat
Ankle Prx/Dis
Ankle Prx/Dis: -3.182 N Frame# 0
Joint angle-Left
Hip Int/Ext
Hip Abd/Add
Hip Flx/Ext
Knee Int/Ext
Knee Abd/Add
Knee Flx/ext
Euler angle-Left
Thigh psi
Thigh theta
Thigh phi
Calf psi
Calf theta
Calf phi
Joint Moment-
Hip Int/Ext
Hip Abd/Add
Hip Flx/Ext
Knee Int/Ext
Knee Abd/Add
Knee Flx/ext
ForcePlate
FZ2
FZ1
FX-1: -0.004 Nt Time 0.00
Gait animation
Joint Force-
Hip Ant/pos
Hip Med/Lat
Hip Prx/Dis
Knee Ant/pos
Knee Med/Lat
Knee Prx/Dis
Ankle Ant/pos
Ankle Med/Lat
Ankle Prx/Dis
Ankle Prx/Dis: -2.808 N Frame# 0
Knee Abd/Add
Knee Flx/ext
Ankle Inv/Eve
Ankle Var/Val
Ankle Pla/Dor
Ankle Pla/Dor: 12.353 Frame# 0
Calf theta
Calf phi
Foot psi
Foot theta
Foot phi
Foot phi: -0.223 rad Frame# 0
Knee Abd/Add
Knee Flx/ext
Ankle Inv/Eve
Ankle Var/Val
Ankle Pla/Dor
Ankle Pla/Dor: 0.174 Nm Frame# 0

Biomechanical Analysis of Discus Throwing at Olympic Games

Project Challenges



Methods

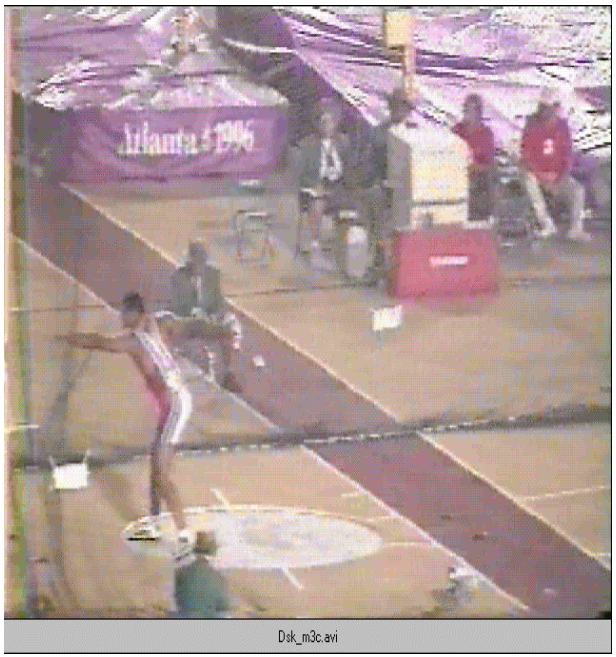
The track & field project involved collecting video records of the preliminaries and final performances of various events for the immediate development of digital movies to be uploaded on the internet.

There Were 18 Throwers During the Qualifying Round and the Best 8 Athletes Competed for the Gold Medal in the Final Round.

Video Cameras Were Placed in Several Locations to Maximize the Data Obtained for the Event

Dsk_m1c.avi

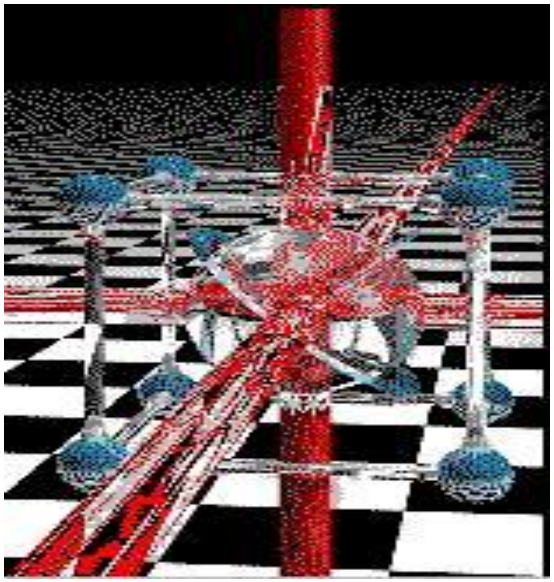
Dsk_m2c.avi



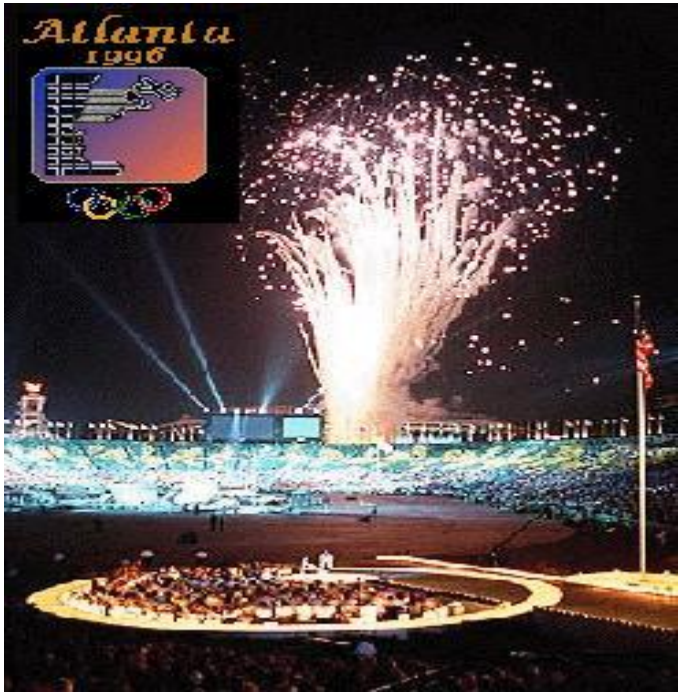
Dsk_m3c.avi

Because the Discus Throw Involves Both Linear and Rotary Motion, the Optimal Data Collection Situation Utilizes at Least Three Cameras Placed Appropriately So That None of the Athlete's Motion Is Obscured

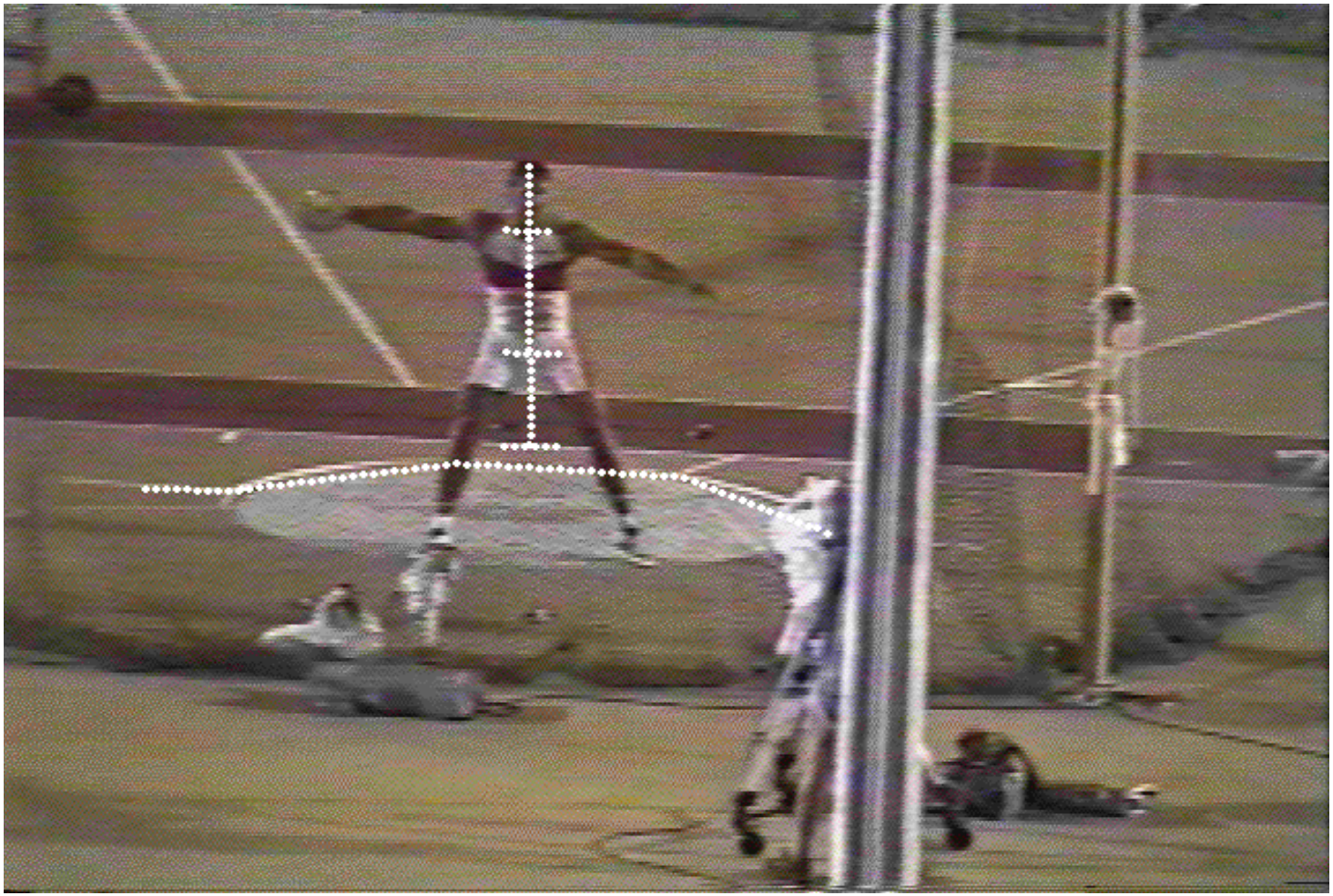
Under Normal Conditions, a Pre-measured Calibration Device or Scale Factor Is Placed in the Field of Study, Filmed, and Used for Subsequent Analyses



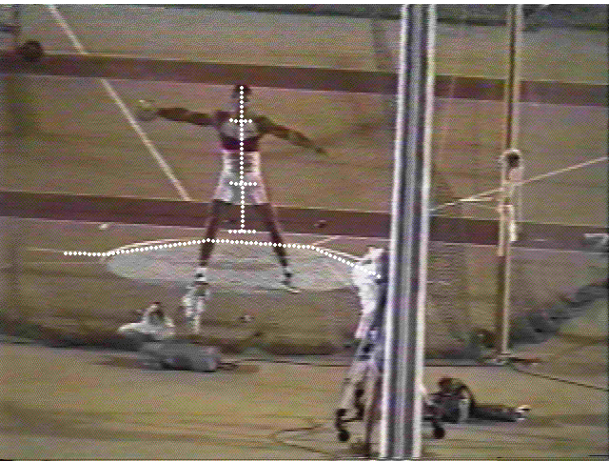
Dimensions of Known Factors and Various Other Measured Objects in the Field of View Were Used for the Calibration Points

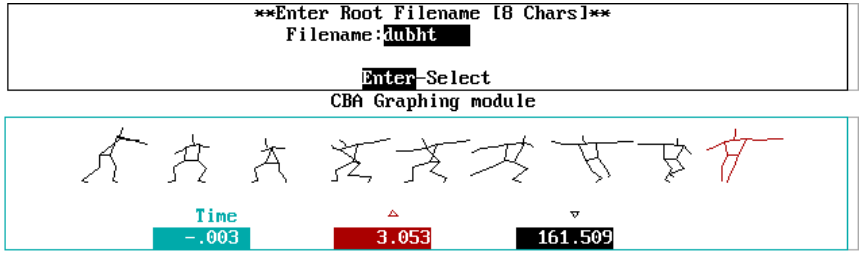


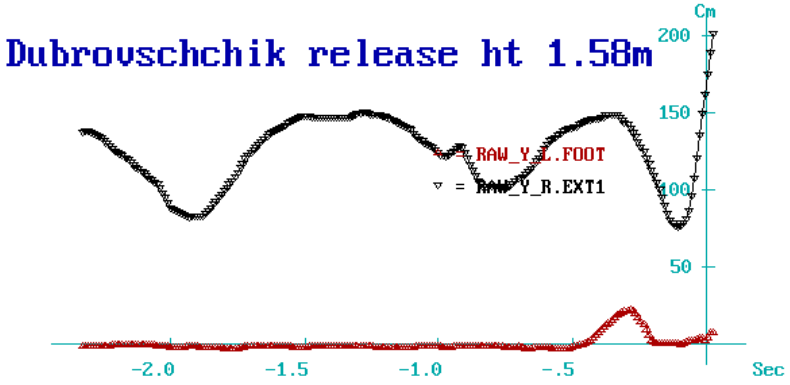
3-D DLT Composite Control Cube



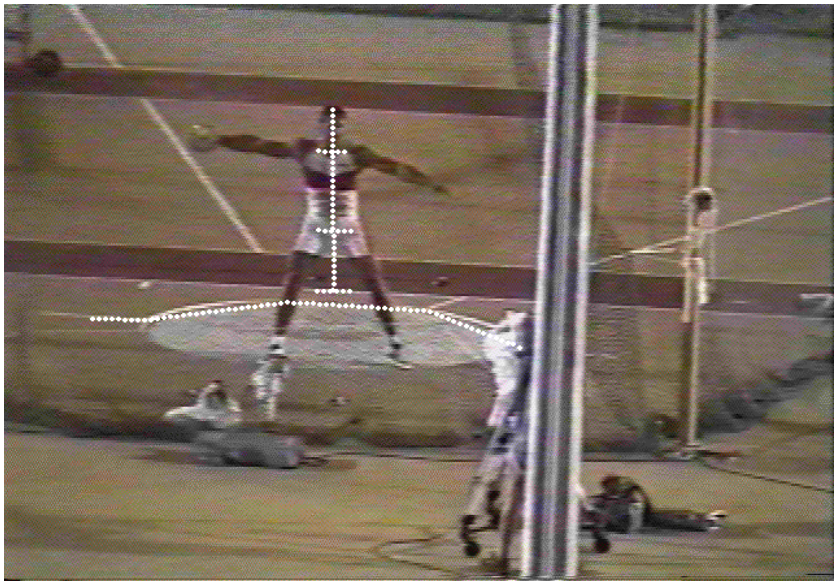
Biomechanical Analytic Procedures



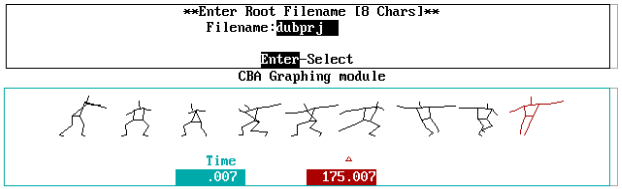


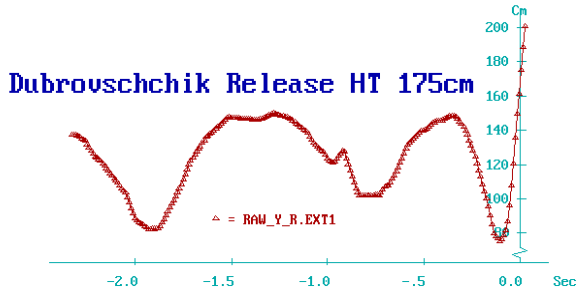


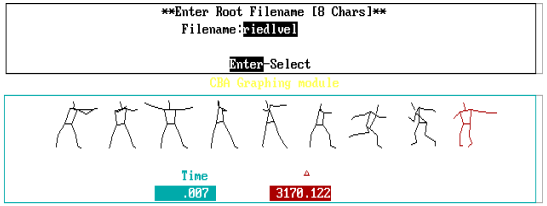
For each camera view, 21 data points were digitized. The 21 points included 19 points for the athlete and 2 additional points located within the throwing circle

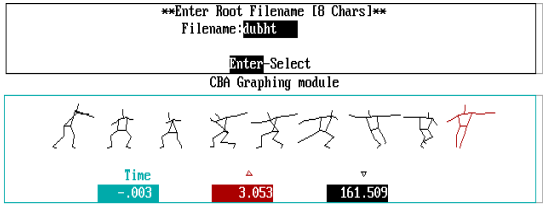


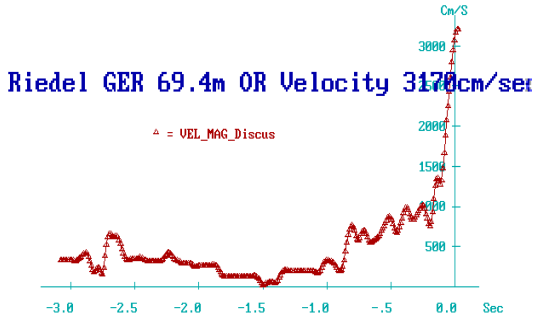
Results

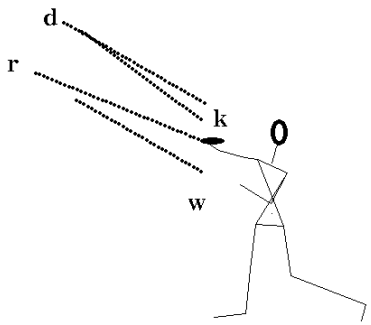


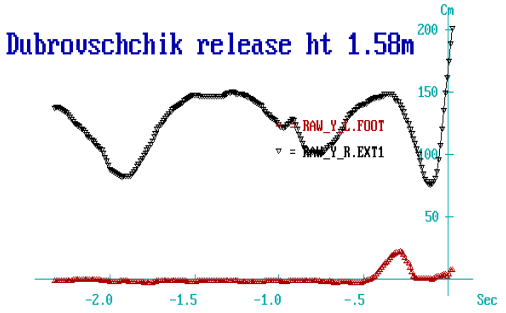












DISCUS THROW KINEMATICS

The Order of Finish Was:

Riedel Representing Germany (GER) Winning the Gold,

Dubrovschchik From Belarus (BLR) Finishing Second,

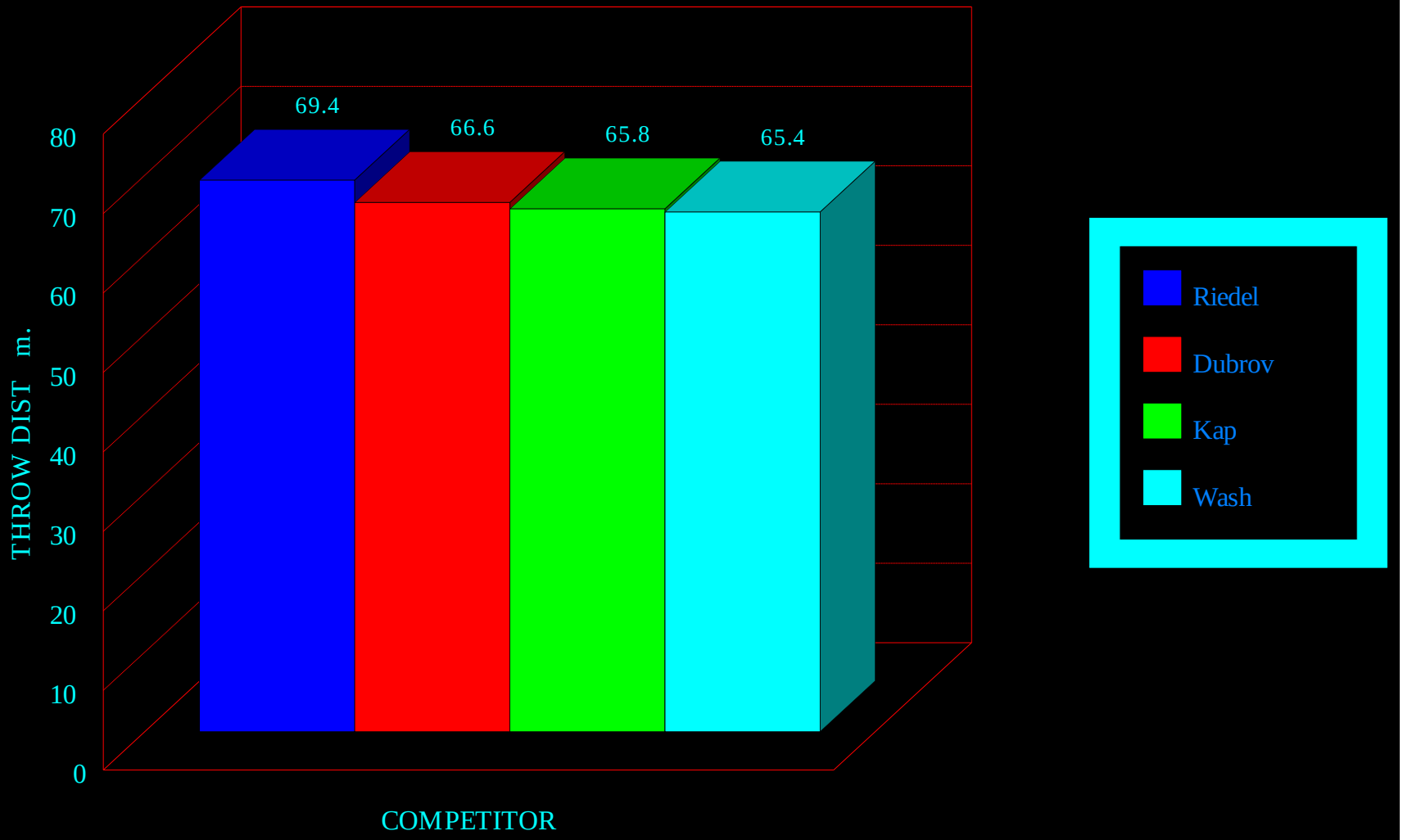
the Bronze Medal Was Won by Kaptyukh From Bulgaria,

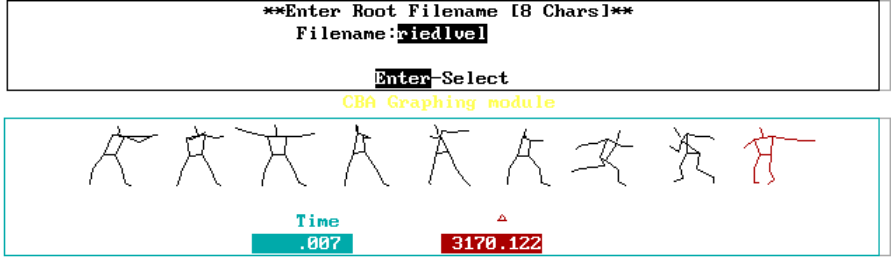
and the Fourth Place Finisher Was Washington Representing the United States.

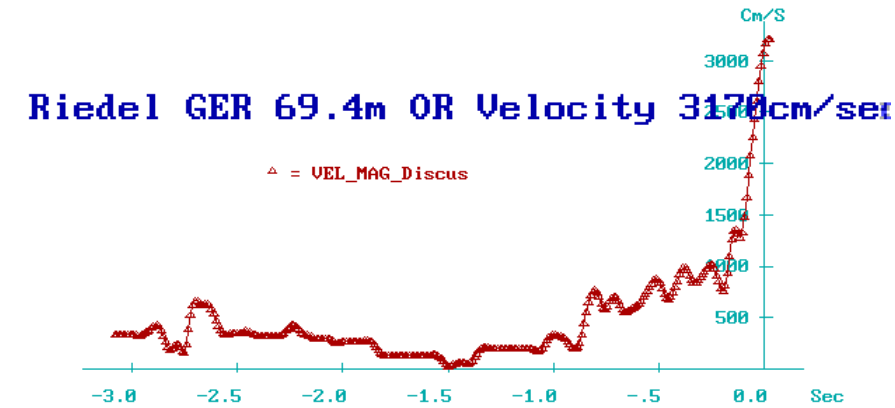
Washington Throwing Kinematics

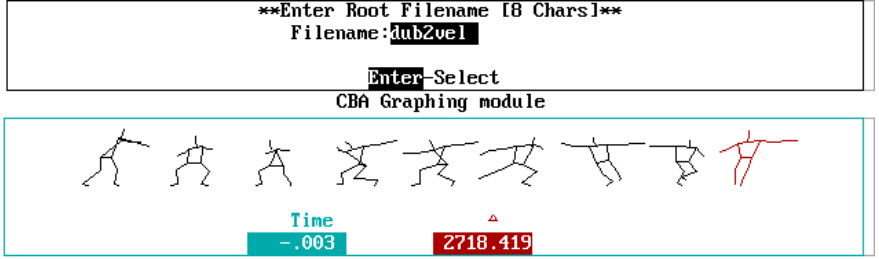
Attempt	Distance m.	Velocity $cm \bullet sec^{-1}$	Projection Angle rad (deg)	Release HT cm	Move Time sec
Best Throw	65.4	2541V_r 2134 V_x	.52 (29.9)	120	1.2
Worst Throw	61.3	2441 V_r 1222 V_x	1.05 (59.9)	140	1.4
% Change	-6.3%	-4.0% V_r -43.0% V_x	+100%	+17%	+12%

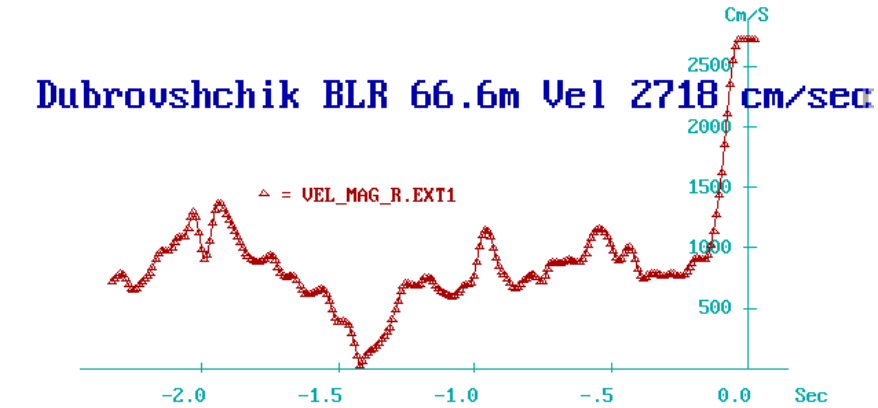
DISCUS THROW DISTANCE m.

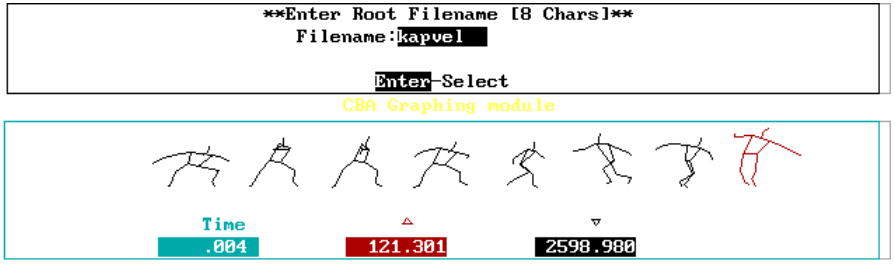


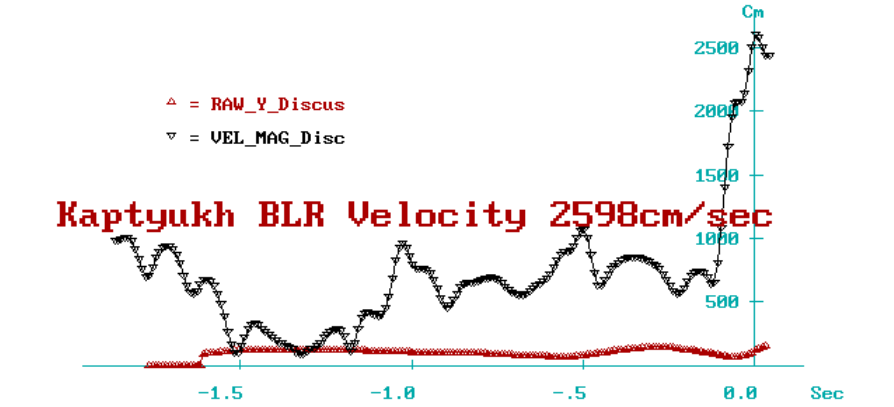

Enter Root Filename [8 Chars]
Filename:riedlvel
Enter-Select
CBA Graphing module
Time
.007
3170.122

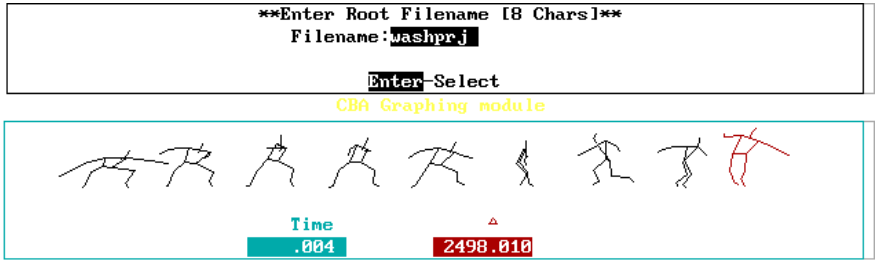

Riedel GER 69.4m OR Velocity 3170cm/sec
Cm/S
= VEL_MAG_Discus
3000
2000
1500
500
-3.0
-2.5
-2.0
-1.5
-1.0
-.5
0.0
Sec

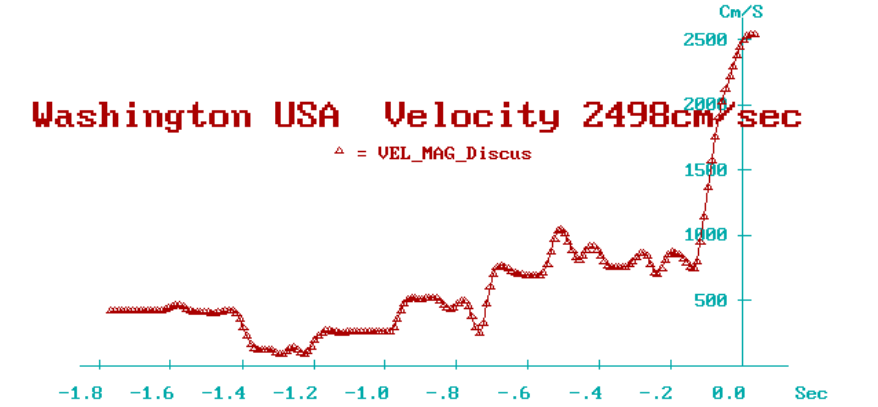

Enter Root Filename [8 Chars]
Filename:dub2vel
Enter-Select
CBA Graphing module
Time
-.003
2718.419


Dubrovshchik BLR 66.6m Vel 2718 cm/sec
Cm/S
= VEL_MAG_R.EXT1
2500
2000
1500
1000
500
-2.0
-1.5
-1.0
-.5
0.0
Sec

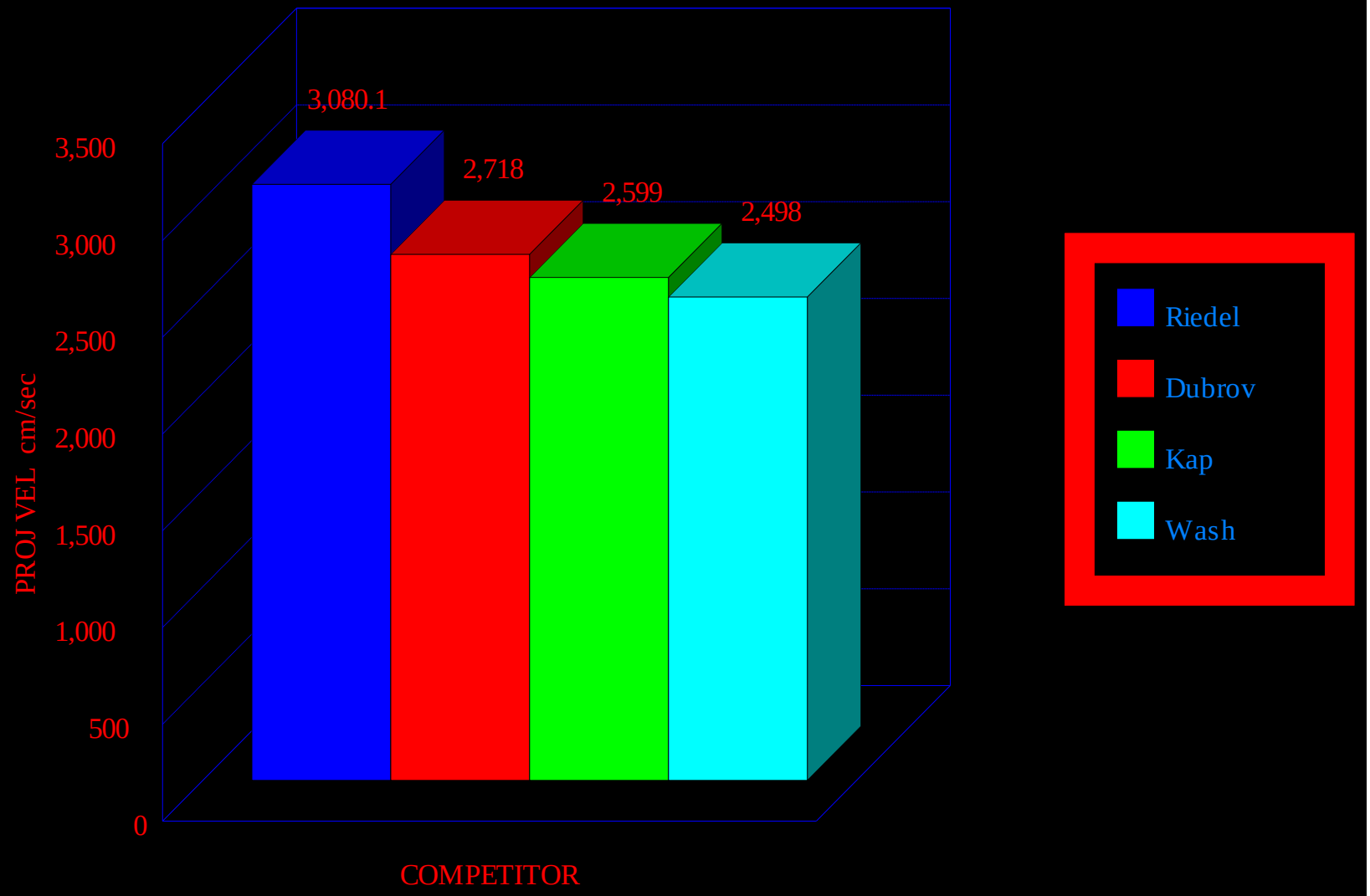

Enter Root Filename [8 Chars]
Filename:kapvel
Enter-Select
CBA Graphing module
Time
.004
121.301
2598.980


Kaptyukh BLR Velocity 2598cm/sec
Cm
= RAW_Y_Discus
= VEL_MAG_Disc
2500
2000
1500
1000
500
-1.5
-1.0
-.5
0.0
Sec


Enter Root Filename [8 Chars]
Filename:washprj
Enter-Select
CBA Graphing module
Time
.004
2498.010


Washington USA Velocity 2498cm/sec
Cm/S
= VEL_MAG_Discus
2500
2000
1500
1000
500
-1.8
-1.6
-1.4
-1.2
-1.0
-.8
-.6
-.4
-.2
0.0
Sec

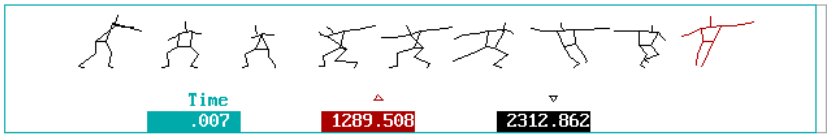
DISCUS PROJECTION VELOCITY cm/sec

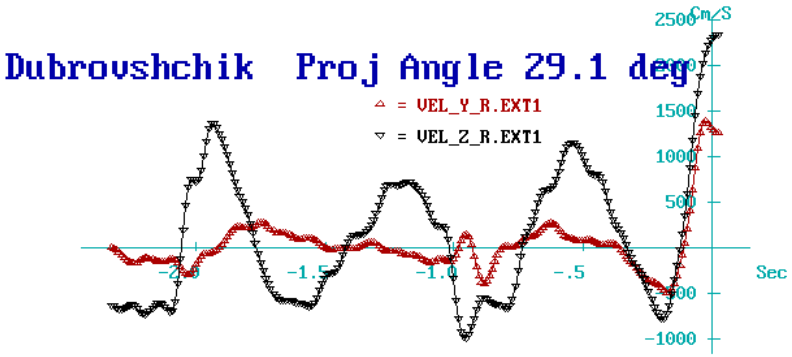


Enter Root Filename [8 Chars]
Filename:dubproja

Enter-Select

CBA Graphing module

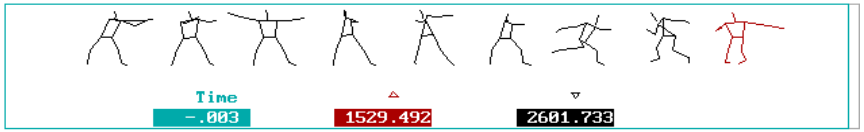


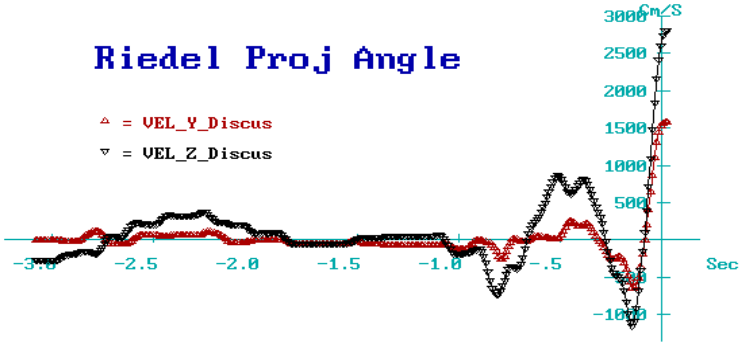


Enter Root Filename [8 Chars]
Filename:riedlpja

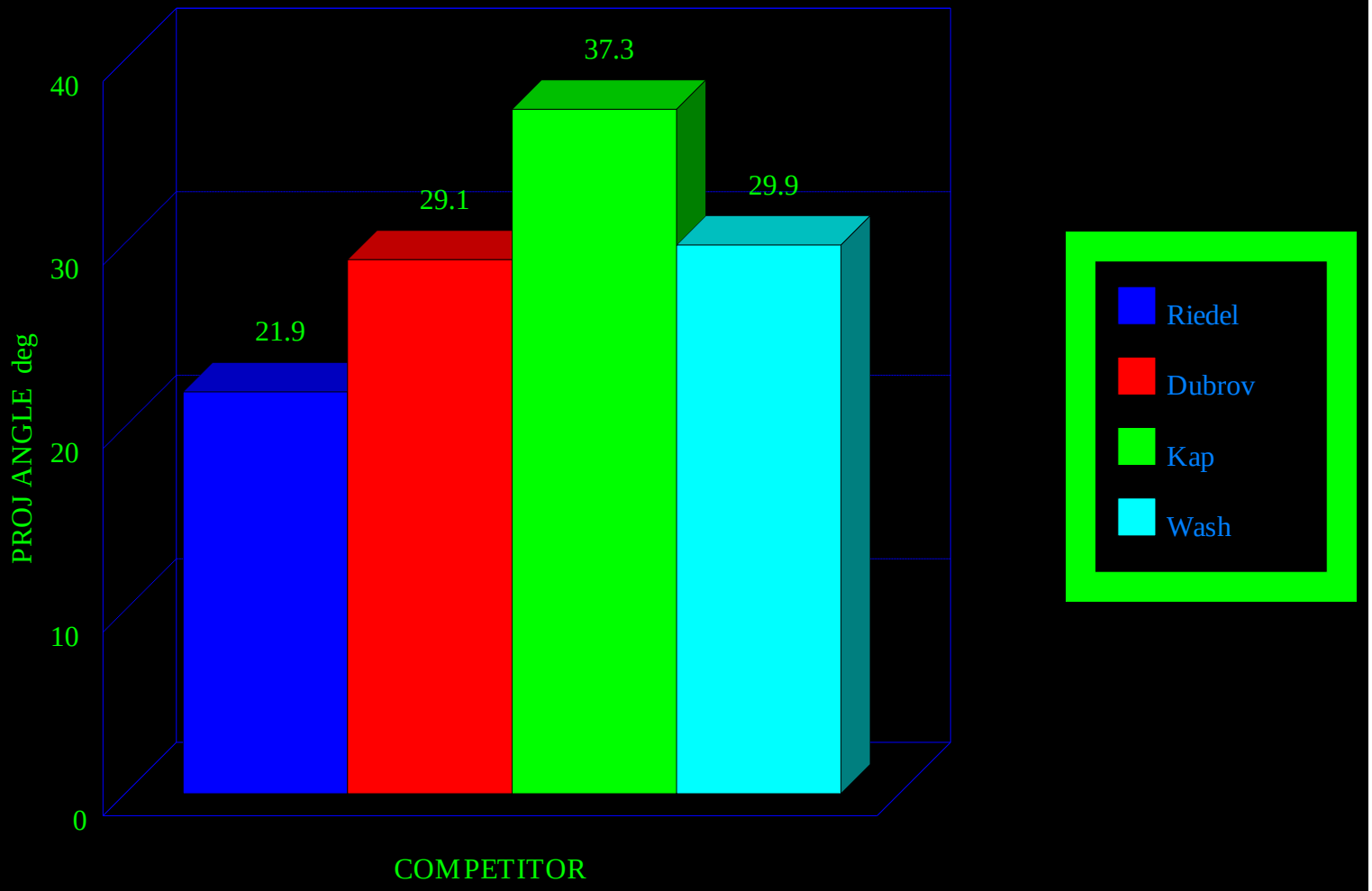
Enter-Select

CBA Graphing module

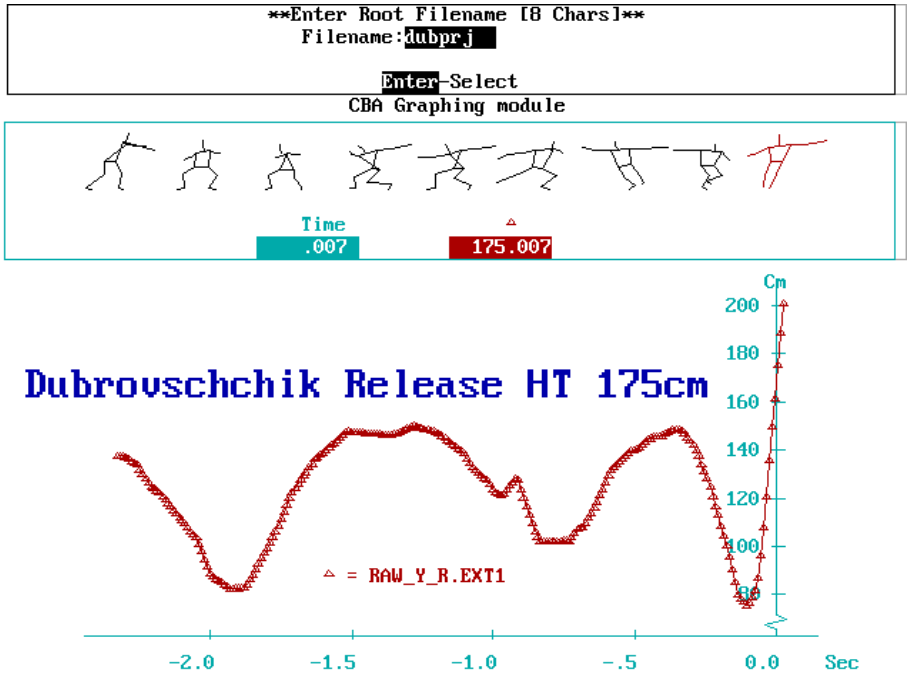


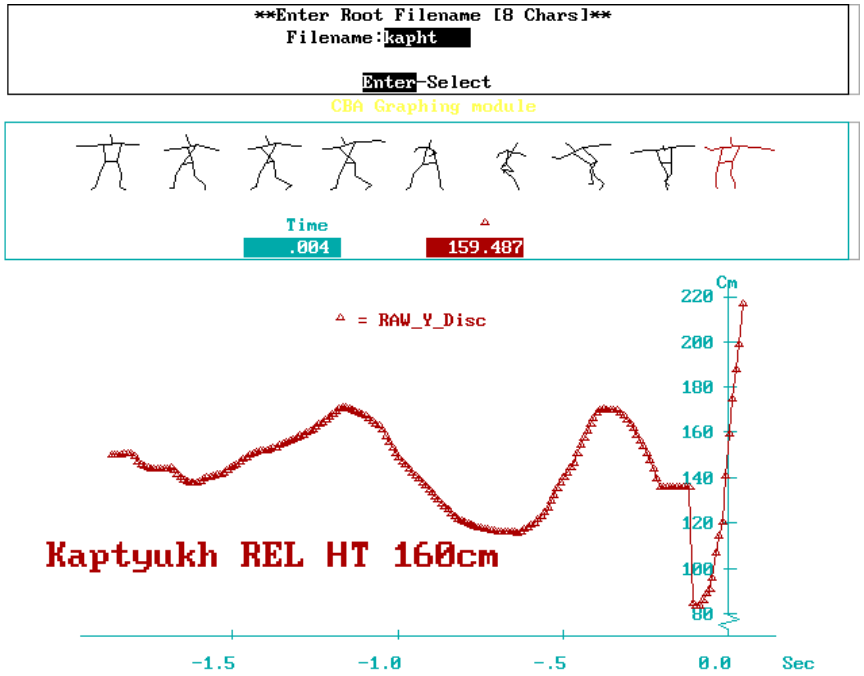


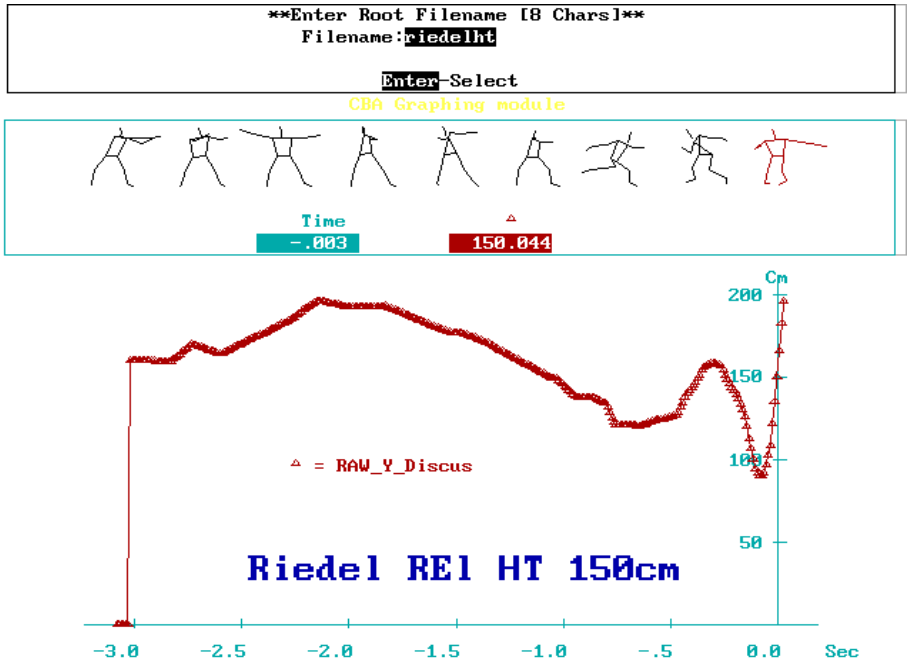
DISCUS RELEASE ANGLE deg

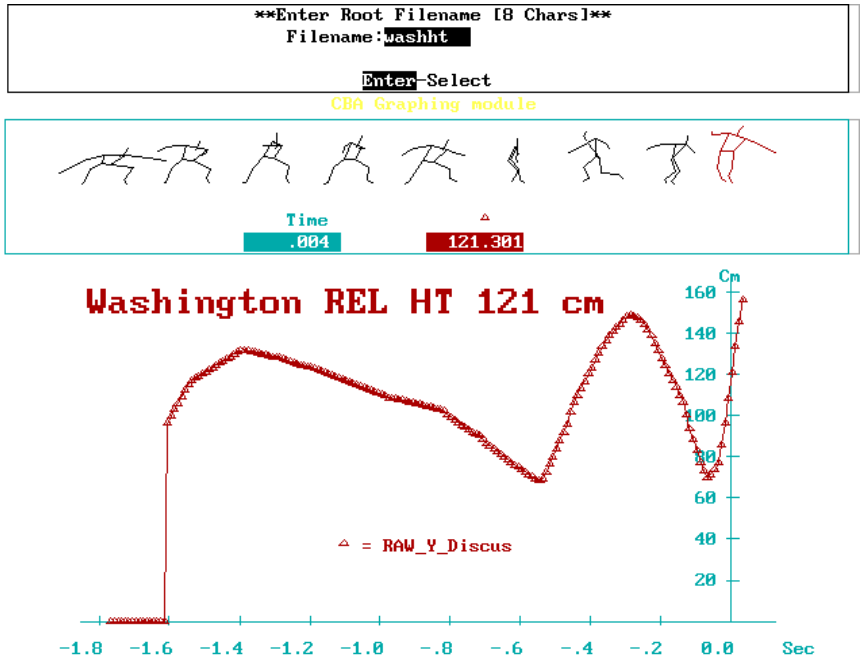


The Heights of Release of the Discus Were 1.5 M, 1.75 M, 1.6 M, and 1.21 M for Riedel, Dubrovschchik, Kaptyukh, and Washington, Respectively.

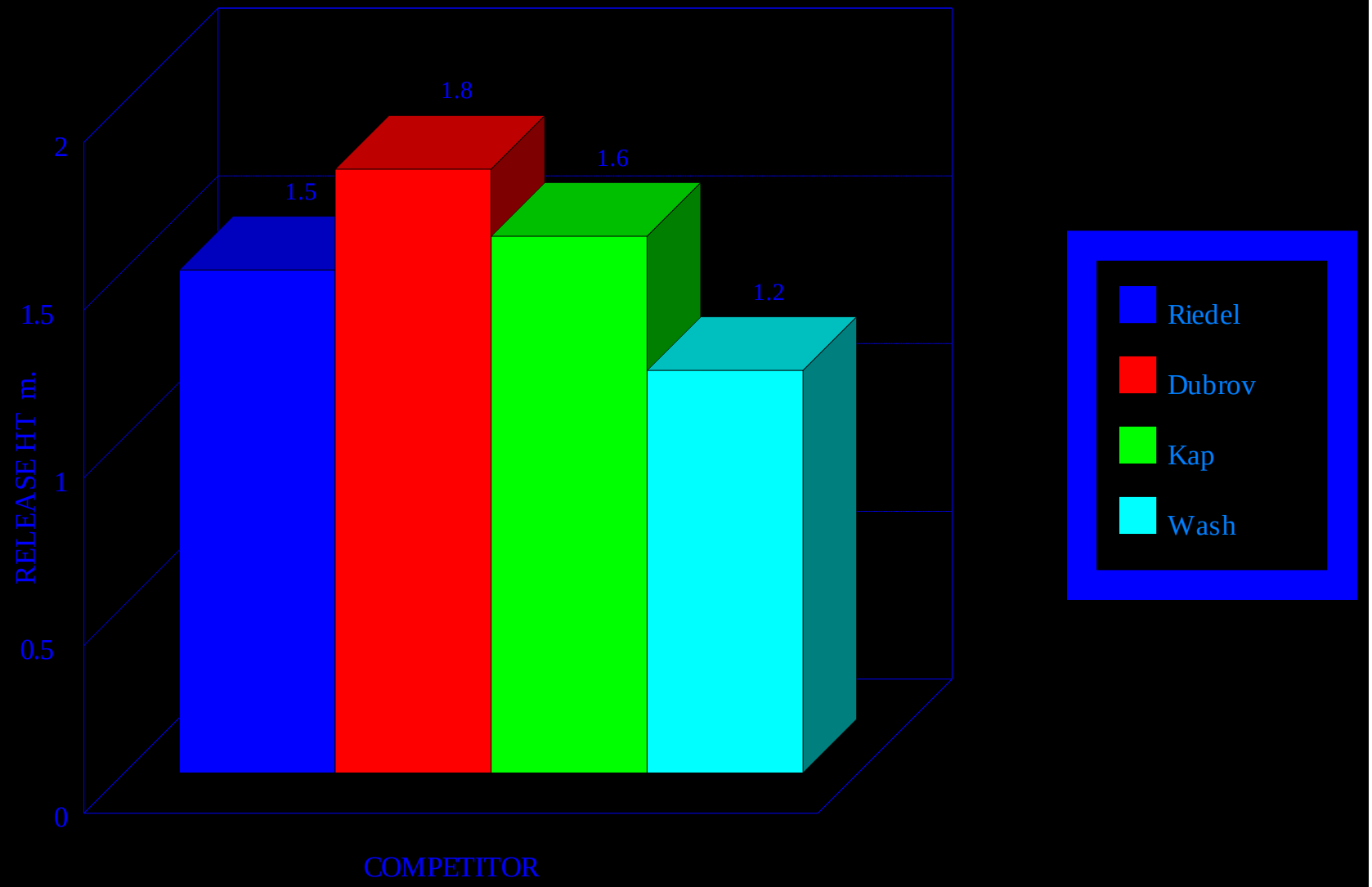

Enter Root Filename [8 Chars]
Filename:dubprj
Enter-Select
CBA Graphing module
Time
.007
175.007
Dubrovschchik Release HT 175cm
Cm
200
180
160
140
120
100
△ = RAW_Y_R.EXT1
-2.0
-1.5
-1.0
-.5
0.0
Sec


Enter Root Filename [8 Chars]
Filename:kapht
Enter-Select
CBA Graphing module
Time
.004
159.487
△ = RAW_Y_Disc
Cm
220
200
180
160
140
120
100
Kaptyukh REL HT 160cm
-1.5
-1.0
-.5
0.0
Sec


Enter Root Filename [8 Chars]
Filename:riedelht
Enter-Select
CBA Graphing module
Time
-.003
150.044
Cm
200
150
100
50
△ = RAW_Y_Discus
Riedel REl HT 150cm
-3.0
-2.5
-2.0
-1.5
-1.0
-.5
0.0
Sec

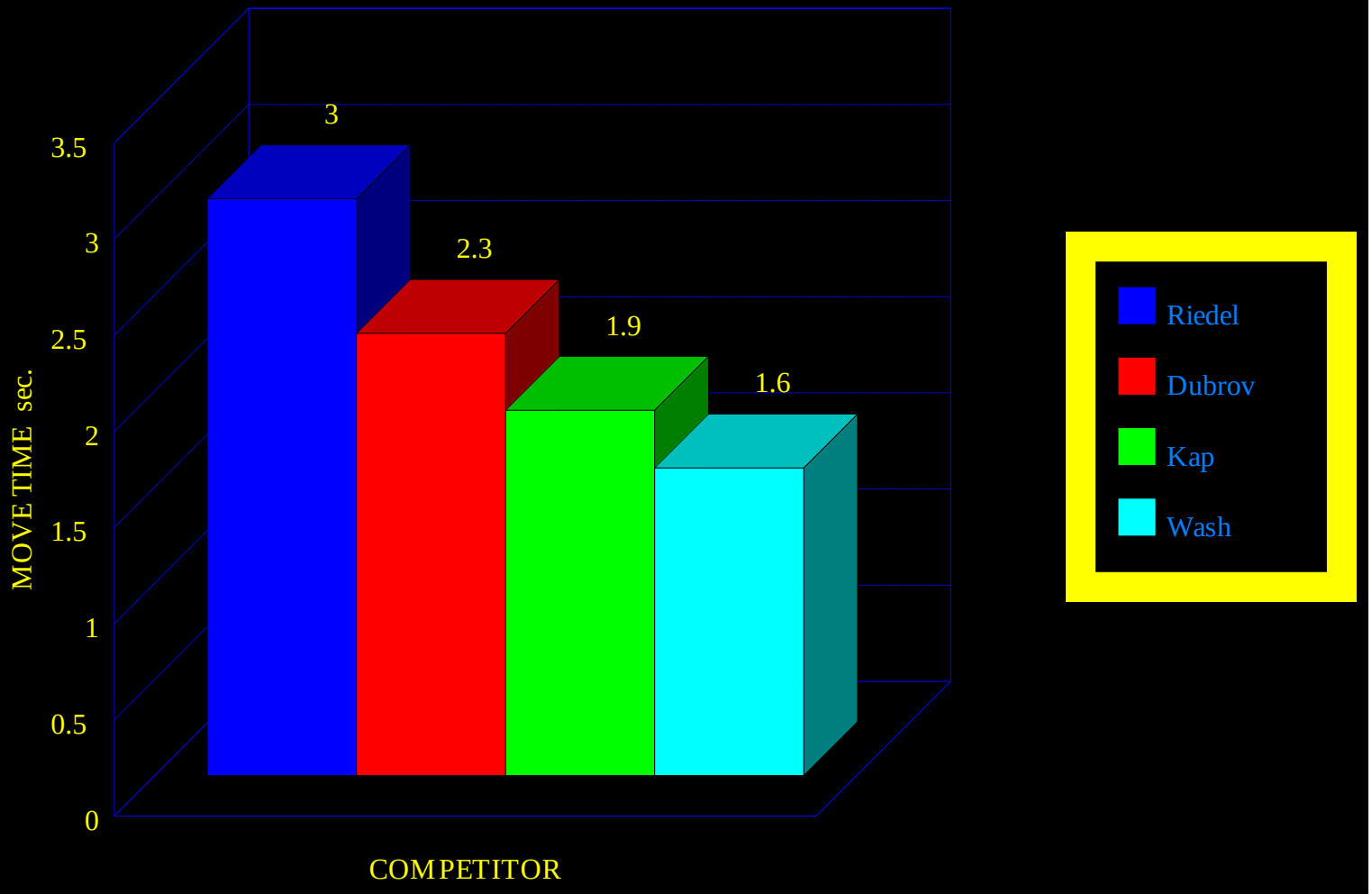

Enter Root Filename [8 Chars]
Filename:washht
Enter-Select
CBA Graphing module
Time
.004
121.301
Washington REL HT 121 cm
Cm
160
140
120
100
80
60
40
20
△ = RAW_Y_Discus
-1.8
-1.6
-1.4
-1.2
-1.0
-.8
-.6
-.4
-.2
0.0
Sec

DISCUS RELEASE HEIGHT m.



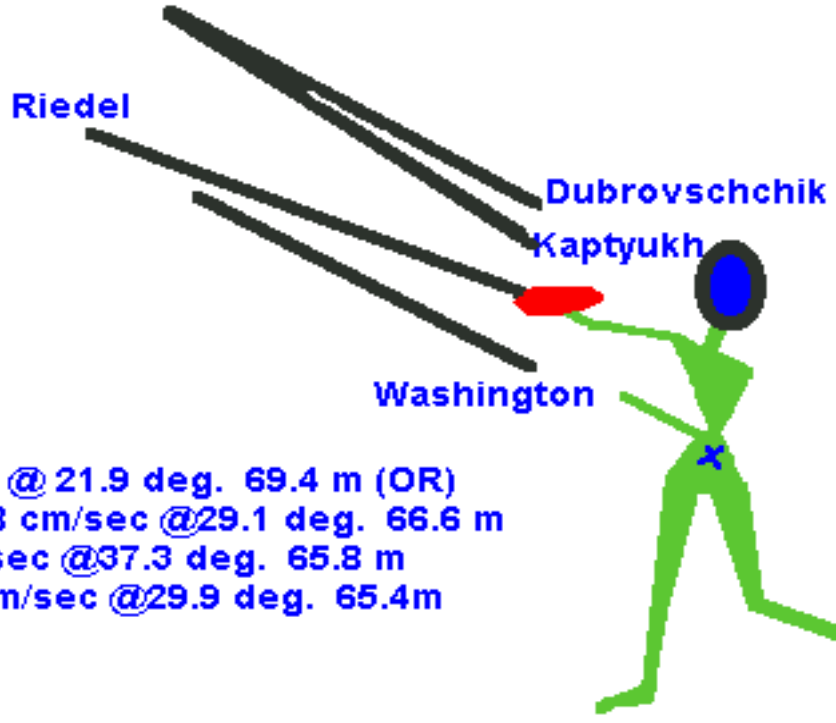
The elapsed times to complete the turns of the throw were 3.0 seconds for Riedel, 2.3 sec for Dubrovschchik, 1.9 sec for Kaptyukh, and 1.6 seconds for Washington.

DISCUS MOVEMENT TIME sec.

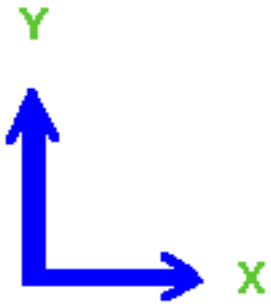


Throwing Kinematics for Top Four Discus Performers at 1996 Atlanta Olympics

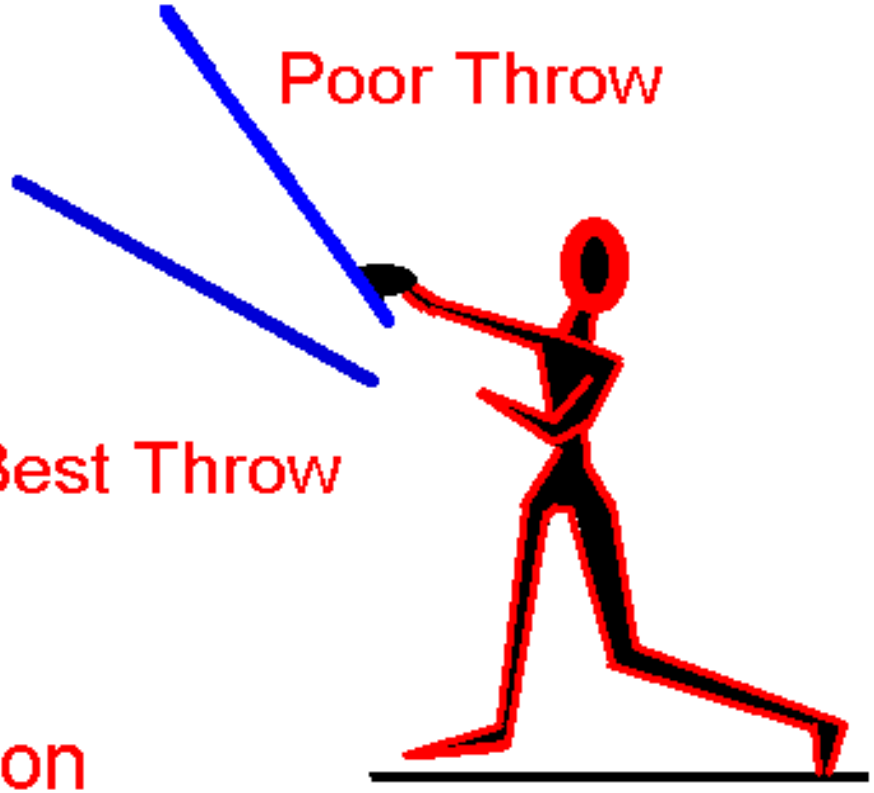
Riedel (Ger)	69.4	3080.1	21.9	1.5	3.0
Dubrovschchik (Blr)	66.6	2718.5	29.1	1.8	2.3
Kaptyukh (Blr)	65.8	2599.0	37.3	1.6	1.9
Washington (USA)	65.4	2498.0	29.9	1.2	1.6



Riedel 3080 cm/sec @ 21.9 deg. 69.4 m (OR)
Dubrovschchik 2718 cm/sec @29.1 deg. 66.6 m
Kaptyukh 2599 cm/sec @37.3 deg. 65.8 m
Washington 2498 cm/sec @29.9 deg. 65.4m

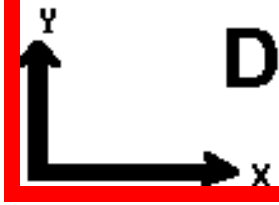


DISCUS THROW KINEMATICS



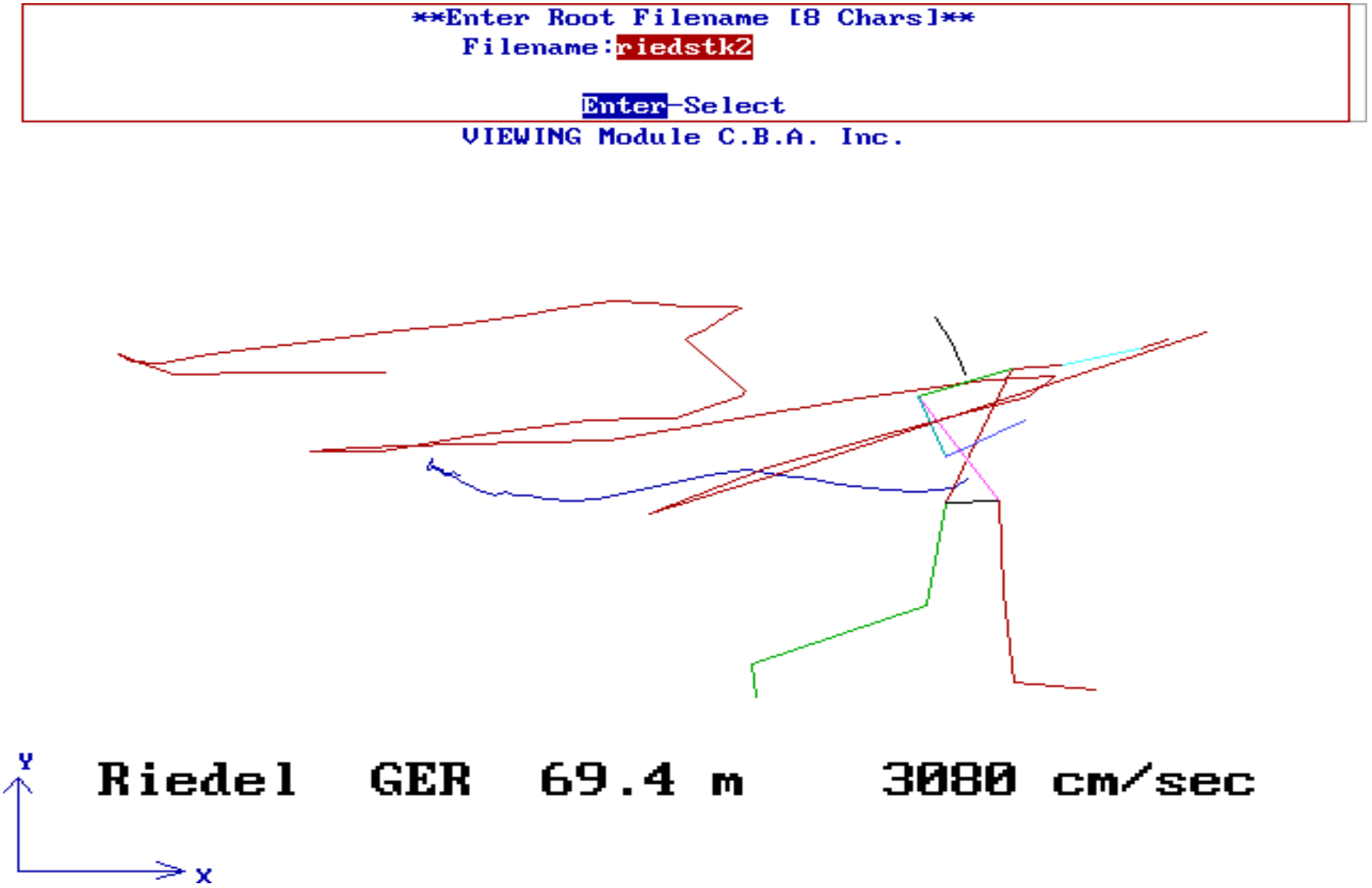
Washington

DISCUS THROW KINEMATICS



Optimum Angles of Projection in the Throws and Jumps

Throwing Pattern Analysis



The Combined Effect of the Projection Velocity, Projection Angle, and Height of Release Resulted in medalist Throws of 69.4 M (Olympic Record) by Riedel (GER), 66.6 M by Dubrovschchik (BLR), 65.8 M for Kaptyukh (BLR), Followed by 65.4 M for Washington (USA). The Aerodynamic Variable of Angle of Attack Was Not Determined for These Throwing Trials

Enter Root Filename [8 Chars]
Filename:washcom4

Enter-Select
VIEWING Module C.B.A. Inc.

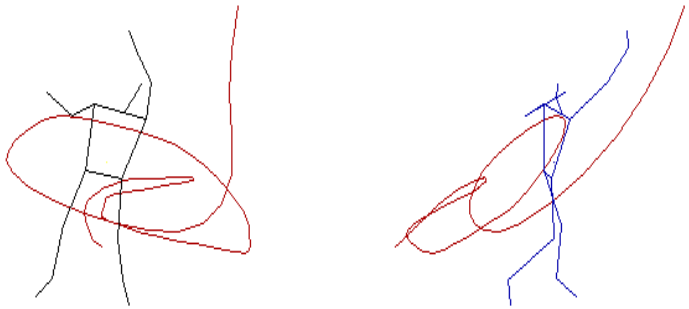
Washington Best Throw

Y
X

Enter Root Filename [8 Chars]
Filename:WASHCOM3

Enter-Select
VIEWING Module C.B.A. Inc.

WASHINGTON POOR THROW



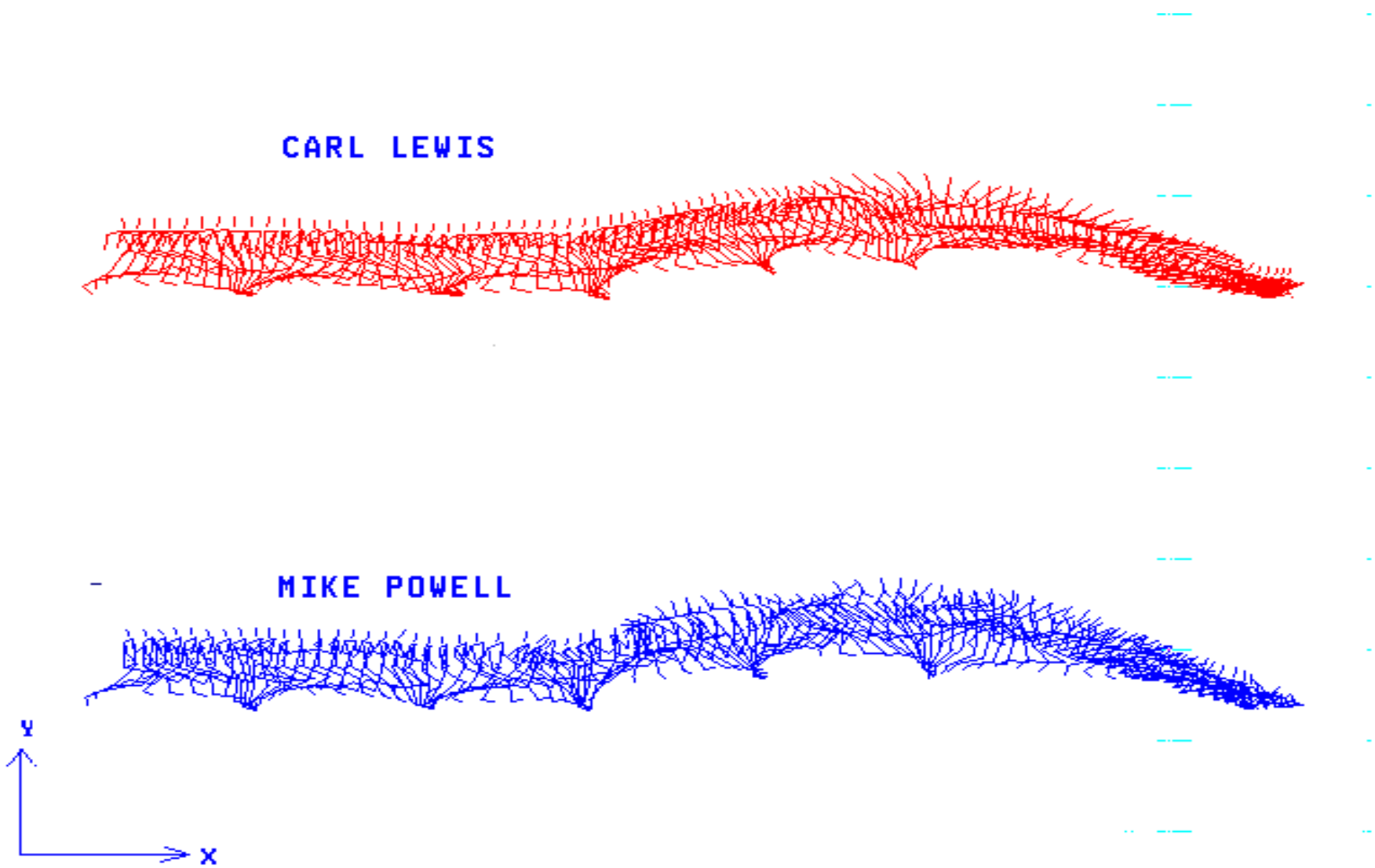
Y
X

Attempt	Max Angular Horizontal Shoulder Velocity $rad \bullet s^{-1}$	Shoulder Ang Velocity at Release $rad \bullet s^{-1}$
Best Throw	26.1	13.7
Worst Throw	20.1	11.2
% Change	-23%	-18%

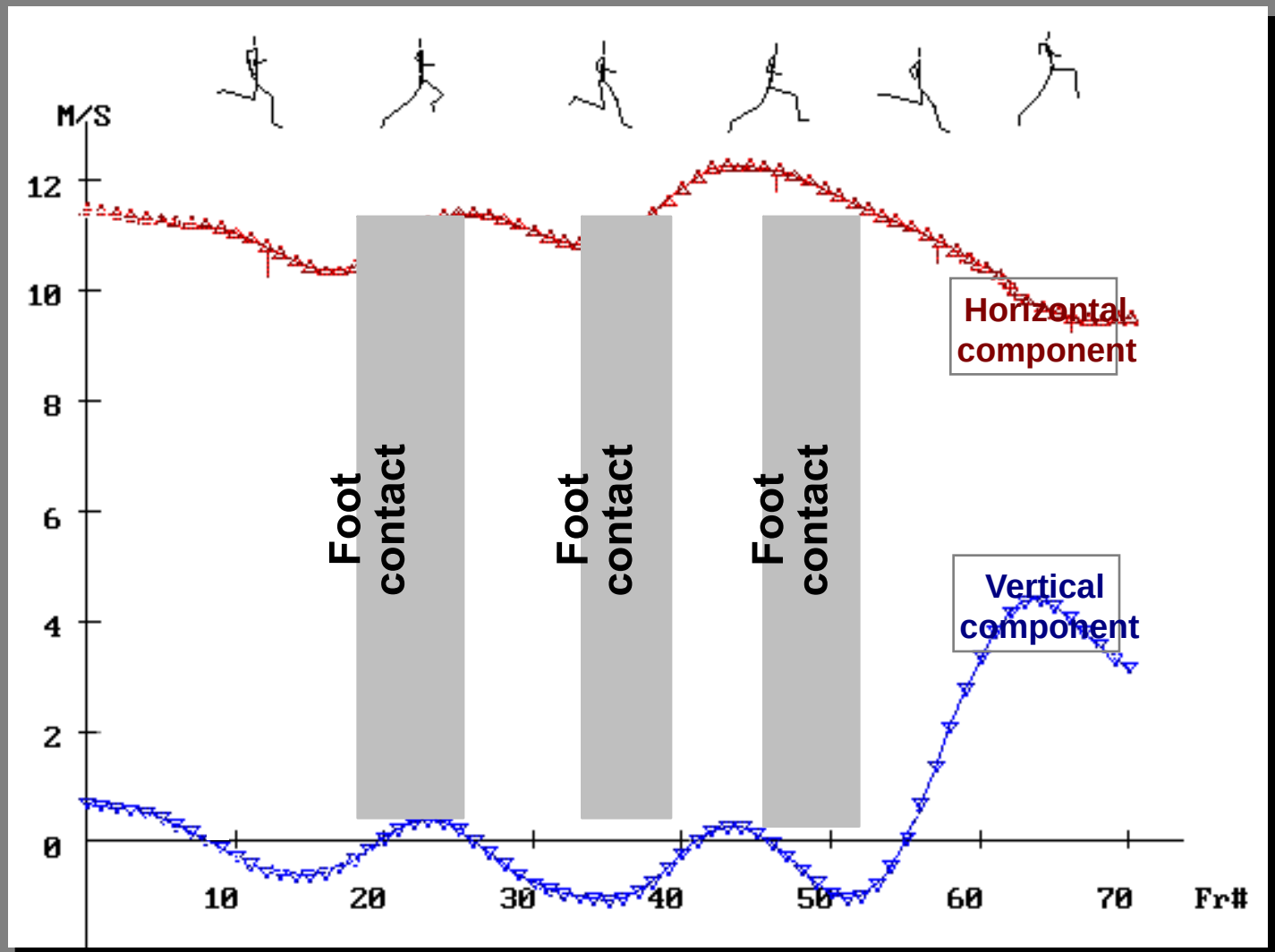
Discus Conclusions

- The poor attempt had a -4% slower resultant disc velocity and a decrease of 43% in horizontal velocity.
- The poor attempt was released at 100% steeper angle.
- Horizontal angular shoulder velocity was 18% slower at release for the poor throw.

THE CASE OF THE LONG JUMP:

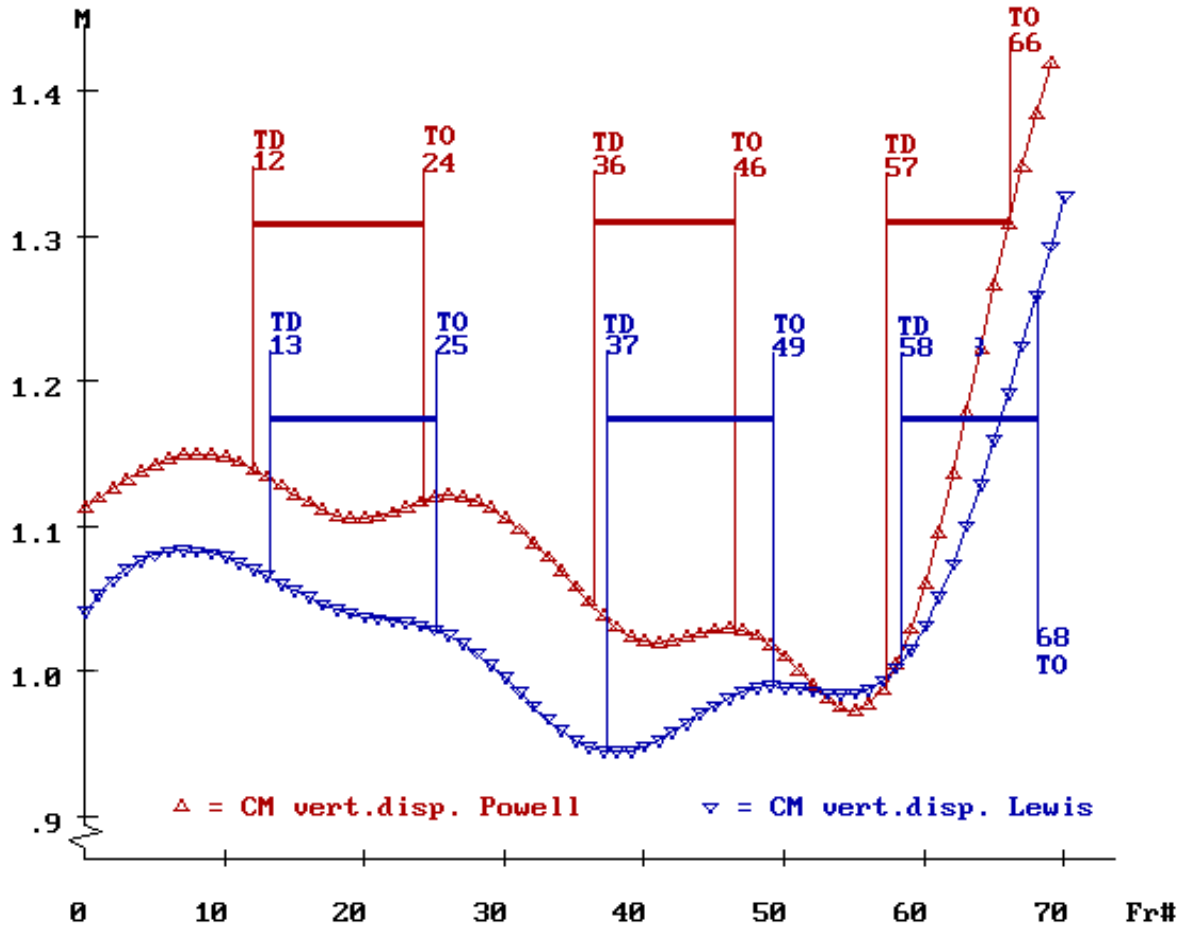


Velocity of the Center of Mass

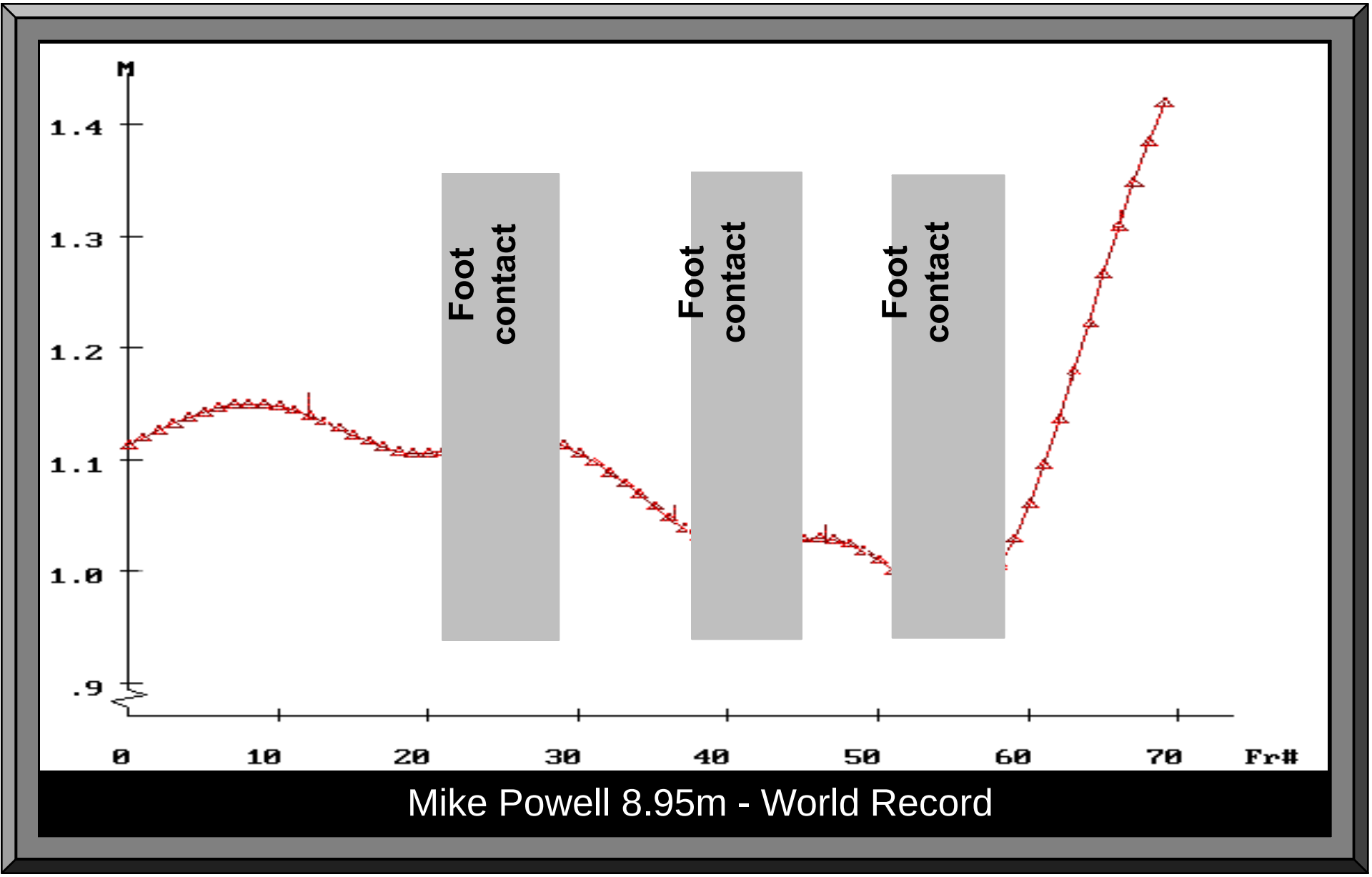


Mike Powell 8.95m - World Record

Change of the Height of CM



Height of the Center of Mass

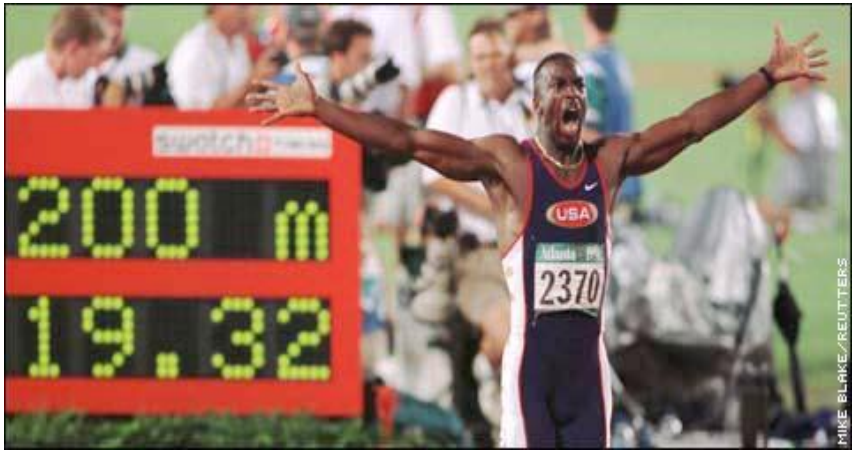


Mike Powell 8.95m - World Record

Comparative Kinematic Characteristics

Parameters of the Long Jump	M.Powell	C.Lewis
General Information		
Official Distance [m]	8.95	8.91
Effective Distance [m]	8.98	8.91
Favorable Wind Velocity [m/s]	0.3	2.9
The Approach		
Average Speed: 11-6m to the Board [m/s]	10.79	11.23
Average Speed: 6-1m to the Board [m/s]	10.94	11.26
The Length of the Third-Last Stride [m]	2.4	2.23
The Length of the Second-Last Stride [m]	2.47	2.7
The Length of the Last Stride [m]	2.28	1.88
The Take-Off		
CM Horizontal Velocity [m/s]	9.27	9.11
CM Vertical Velocity [m/s]	4.21	3.37
Angle of Projection [deg]	24.1	20.3
Angle of body Lean at Touch-Down [deg]	71.8	77
Angle of body Lean at Take-Off [deg]	73.9	67.5

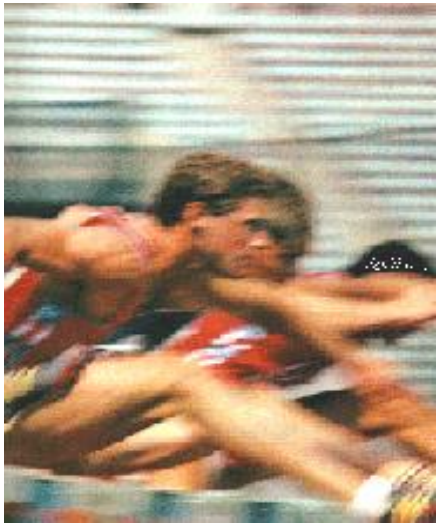
Hammer1.avi


200 m
19.32
USA
2370
MIKE BLAKE/REUTTERS


3478
3298
5
3
Ross Kinnaird/Allsport

RUN1.AVI

Hurdle1.avi



PV1.AVI

The Future – The Virtual Coach

- Virtual Biomechanic Desk
  - Locate and download your favorite Biomechanical Data from one convenient, easy-to-use interface.
  - Software that allows users to share Biomechanical libraries with each other no matter where they are located. Coach_virtual provides a search capability for videos, 3D/2D Files capability for users to communicate in forums of like interest.
  - Each Coach is a download/upload source
  - Each User Computer, when it is on, it becomes a shared directory
  - For more information: http://www.arielnet.com

The Future

- A user records and stores Video file in a specific folder on his or her hard disk
- A central directory maintained by Coach.com keeps track of which users are logged on, cataloging by title and researcher/biomechanist the activity in each user's special folder
- A user searches through the Coach.com directory for a desired activity or sports. Once the activity is downloaded it can be used for further analysis or observation. This file can also be sent to another person as e-mail or attachment
- Any user folder can be shared with the rest of the World
- Coach.com monitor and publish the catalogue of activities and sports world wide
- Biomechanical Analysis from TV broadcast

THANK YOU