Application of Motion Analysis Technology to Olympic Sports

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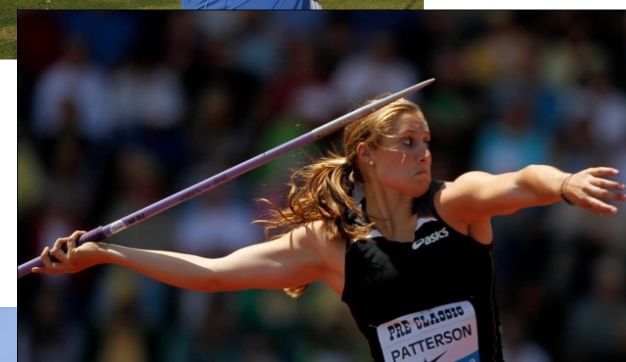
US Olympic Training Center, Chula Vista CA

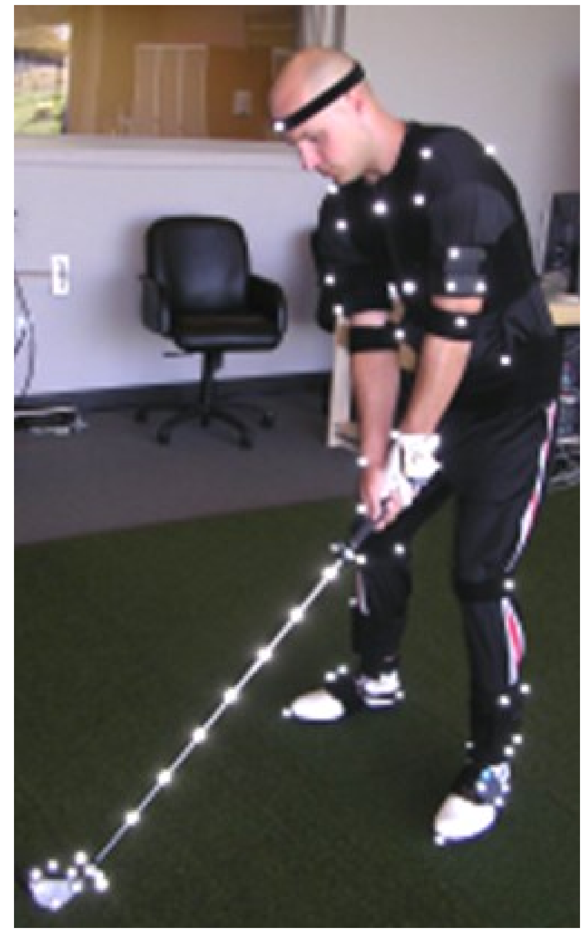
Chula Vista
Training Center



Definitions

Motion Analysis

- The science of analyzing human movement using the principles of physics
  – Clinical Motion
  – Sports Motion
- Steps
  – Capture the motion with video or sensors
  – Compute physical parameters
  – Analyze using statistics
  – Compare the motion to the best in the world
- Principle tool used in Biomechanics



Biomechanics

- The study of human motion using the principles of physics, engineering, anatomy and physiology

- In sports we use biomechanics to provide rational to why we teach specific techniques

- Two goals of biomechanics
  - Rapidly Improve Performance
  - Reduce Injury Risk

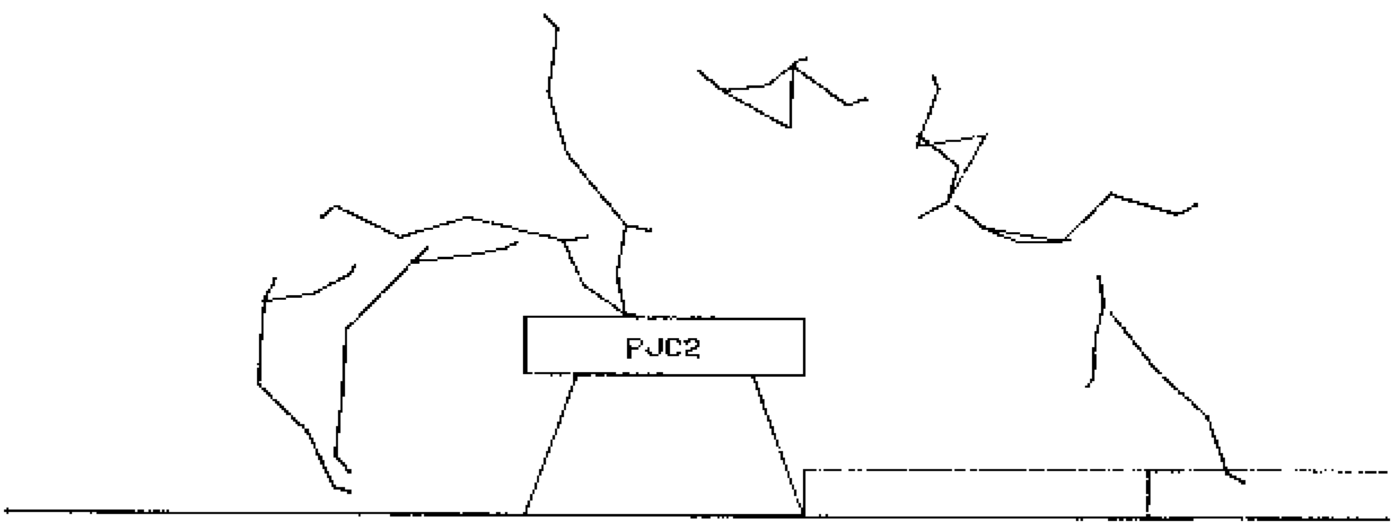
Motion Analysis Methods

A history of ways to capture and analyze human motion from my experience

- Electrical Engineering Degree, UNSW, Sydney, Australia

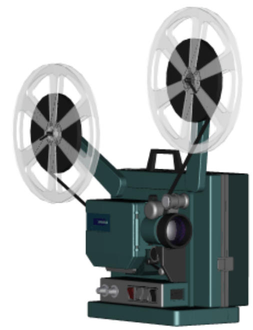
- Olympian in Gymnastics
  - 1976 Montreal
  - Came to Arizona State University to prepare for 1980 Olympics

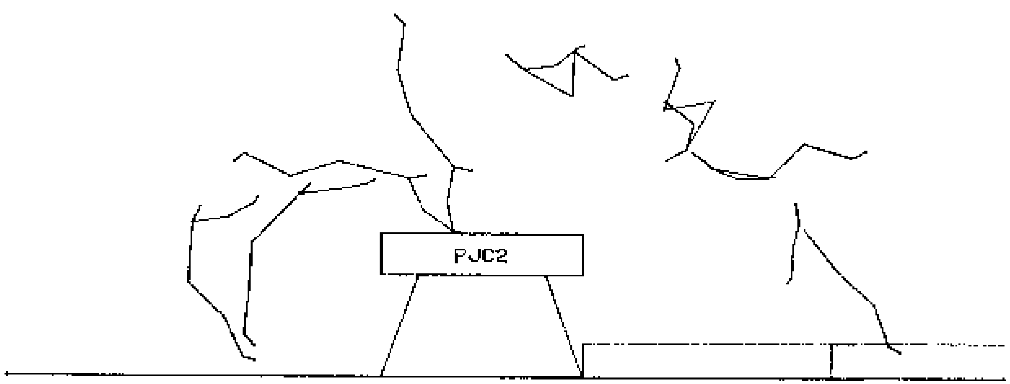
- Master of Science Degree
- Physical Education, Biomechanics
- ASU, Tempe, Arizona
  - Developed 2D Film Analysis System for Thesis
  - Analysis of the Handspring Front Flip on Vault



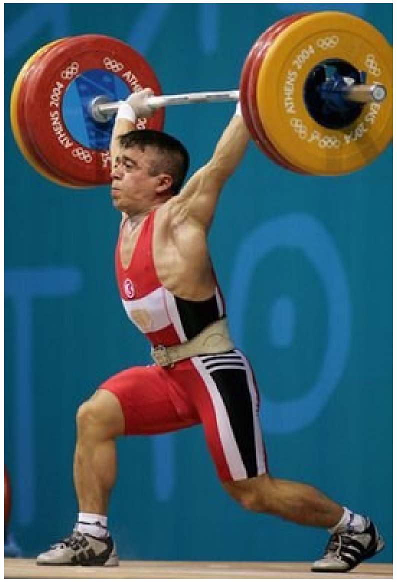
Manual Digitizing from Film

- Locam 16mm Film Camera
- 16mm Projector
- Graphics Digitizing Tablet
- Digitize Joint Centers
  - Frame by Frame
  - Crosshair Cursor
  - Very Laborious
- Tektronics 4052 Computer
  - Wrote my own software



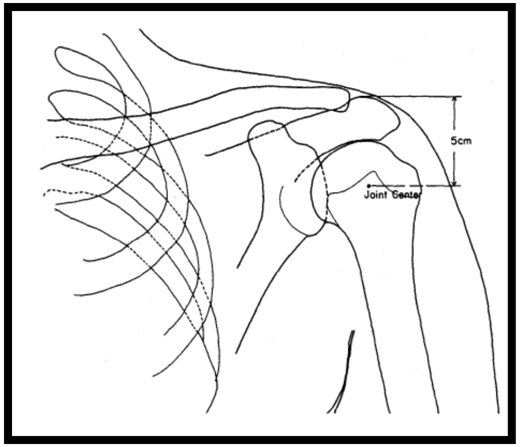


- Research Engineer,
  Sports Science Program
  Olympic Training Center, Colorado Springs
  - Co-Developed 2D Optical Motion Analysis System
- Started a Company called
  Peak Performance Technologies

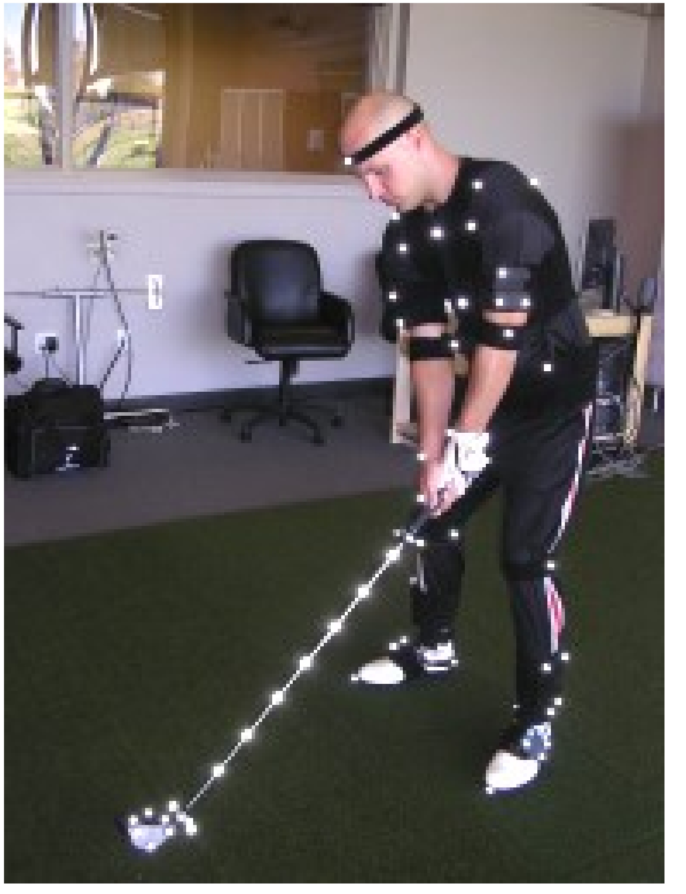


3D Manual Digitizing from Video

- Peak Performance Technologies Inc.
- Multiple Camera Views
- Calibration Frame
- Digitize Body Points in Sequential Images
  - Crosshair Cursor on Joint Centers
- Advantages
  - No need to bother the athlete
  - Only way to get data in a competition
- Disadvantages
  - Tedious and time consuming
  - Impractical for immediate feedback
  - Digitizing Error
- Used this at Barcelona Olympics 1992
  - IOC Project
  - Gymnastics, Diving, Track and Field
- Still use this Method Today
  - High Jump, Discuss, Hammer



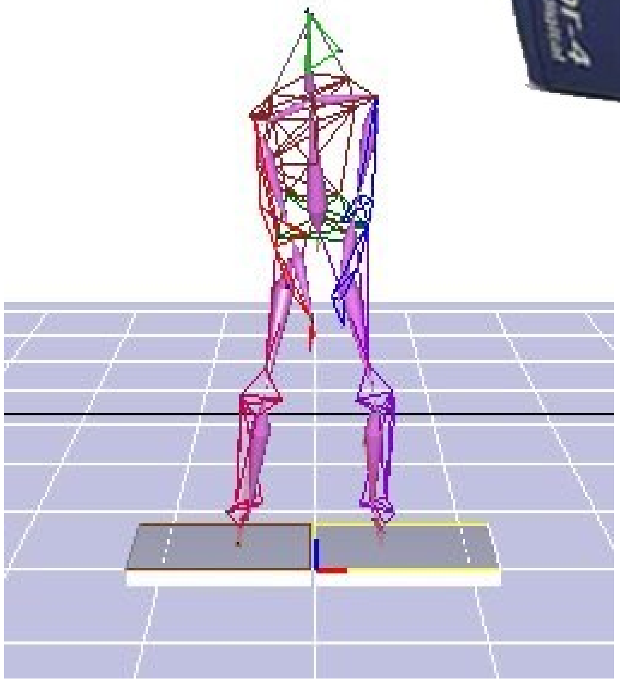
Optical



- Reflective Markers
- Video or Infrared Cameras
- Automatic Tracking
  - Markers automatically tracked
  - Lots of cameras (8 – 24 or more)
- Advantages
  - Markers are light
  - No Wires
  - High Sample Rates (500Hz)
  - Can now do real-time display
- Disadvantages
  - Can’t be used in Sunlight
  - Maybe time consuming
  - Expensive
  - Complex

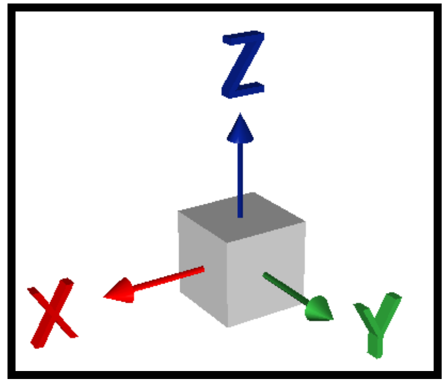
Optical Systems

- Qualisys
- Motion Analysis Corp.
- STT
- Vicon
- Natural Point
- Motion Reality



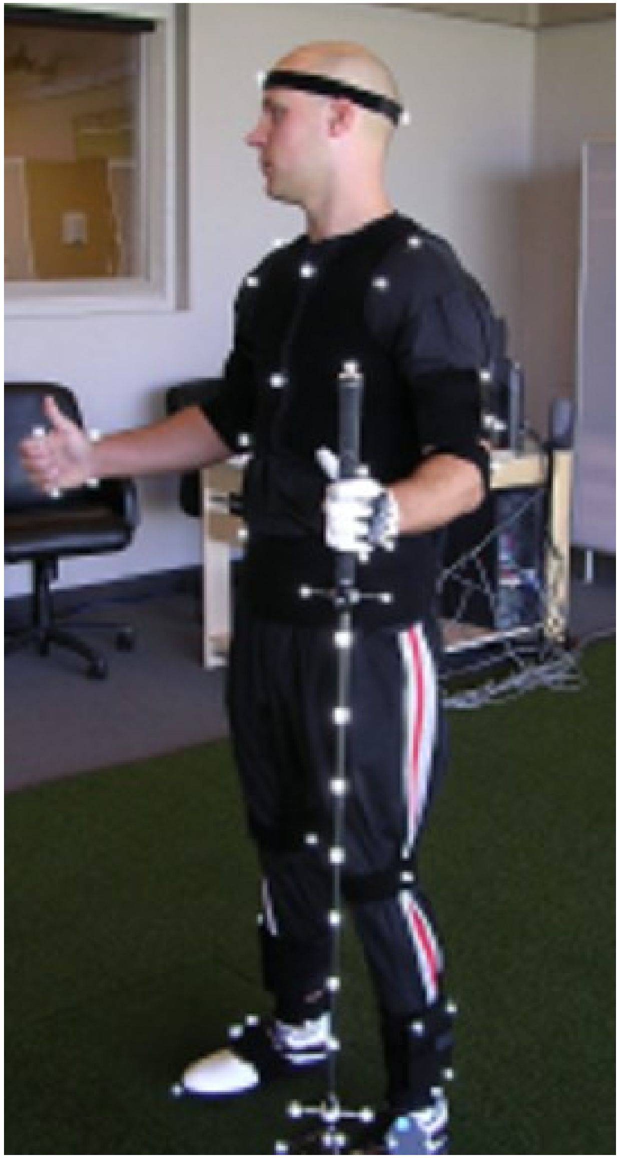
Electromagnetic

- Transmitter and Sensors
  - 4 to 12 Sensor Typical
- Advantages
  - Small Sensors
  - Fast 240 Hz
  - Real-Time
  - 6 Degrees of Freedom
  - Accurate Anatomical Alignment
  - Full Body Capture
- Disadvantages
  - Wired
  - Metal Sensitive (but works on any club)



Anatomical Alignment

- Align Markers Directly to Body
  - Use Digitizing Pen on Body Points
    - Used by AMM 3D-Golf
  - Use Static Markers on Body Points
    - Typically for Optical Systems
- Get "True" Body Angles and Positions
- More accurate but more time consuming



Wireless Electromagnetic – G4

Self Contained and
Battery Operated

Quick to Set Up
and Teatherless

Inertial Systems – K-Vest

- 3DOF
  - Bend
  - Side Bend
  - Turn
- Inertial Hardware
  - 3DOF
  - Portable
  - Each Sensor is Wireless

Intertial Systems - Noitom

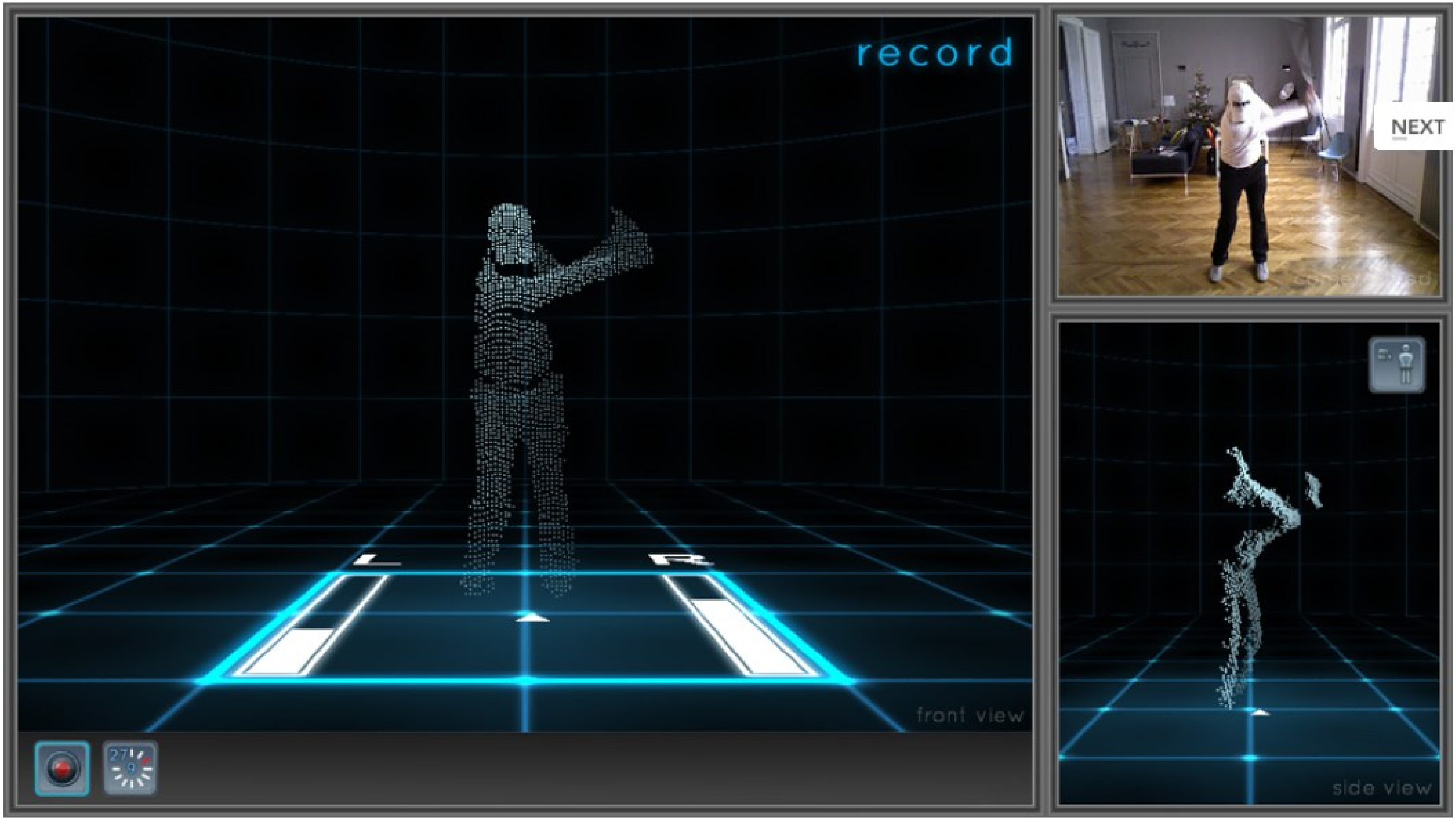
Inertial - Xsens

Many Inertial Companies

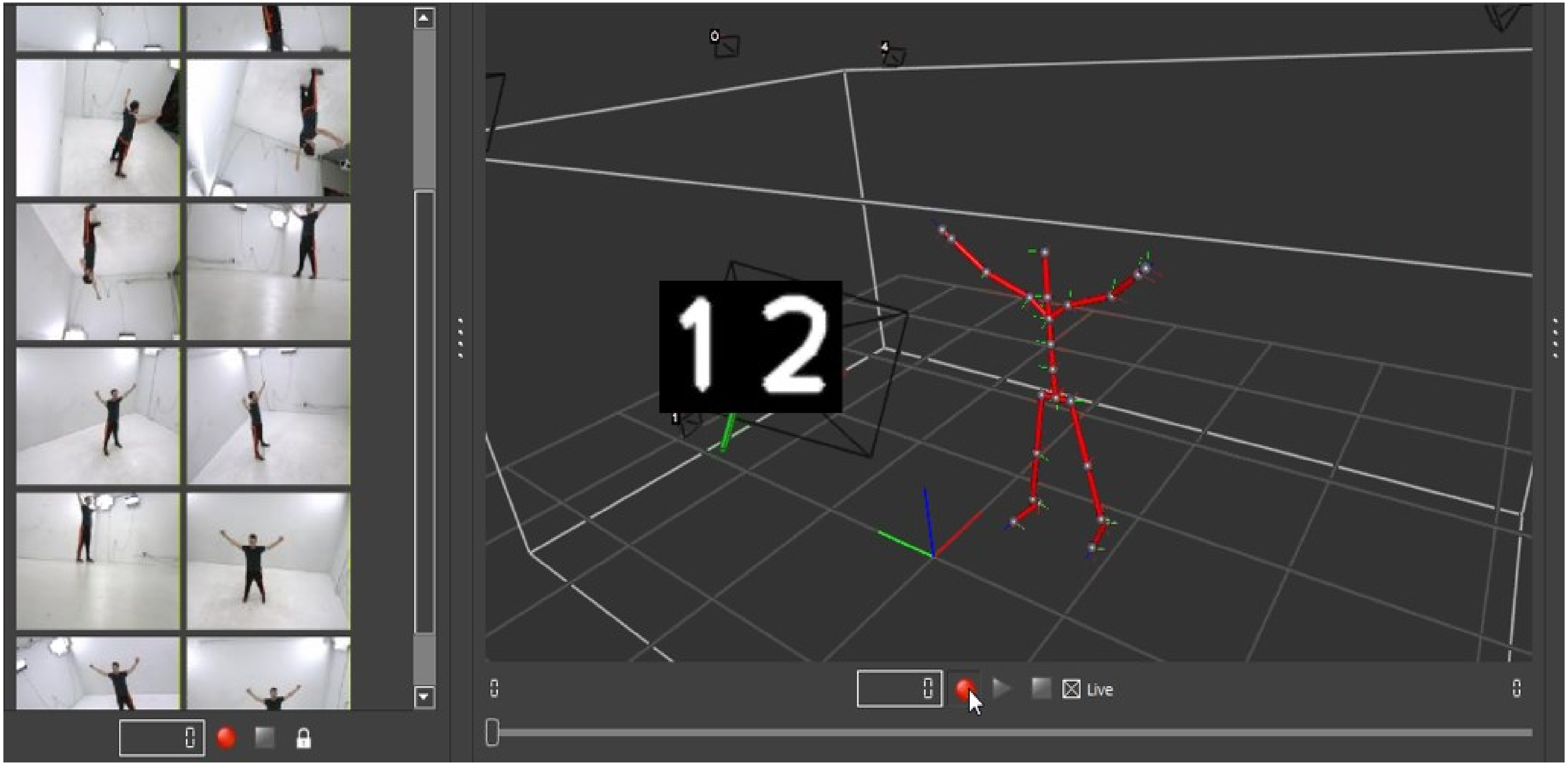
- Zepp
- Blast Motion
- YEI
- APDM

Markerless Tracking

Markerless Systems – Swing Guru

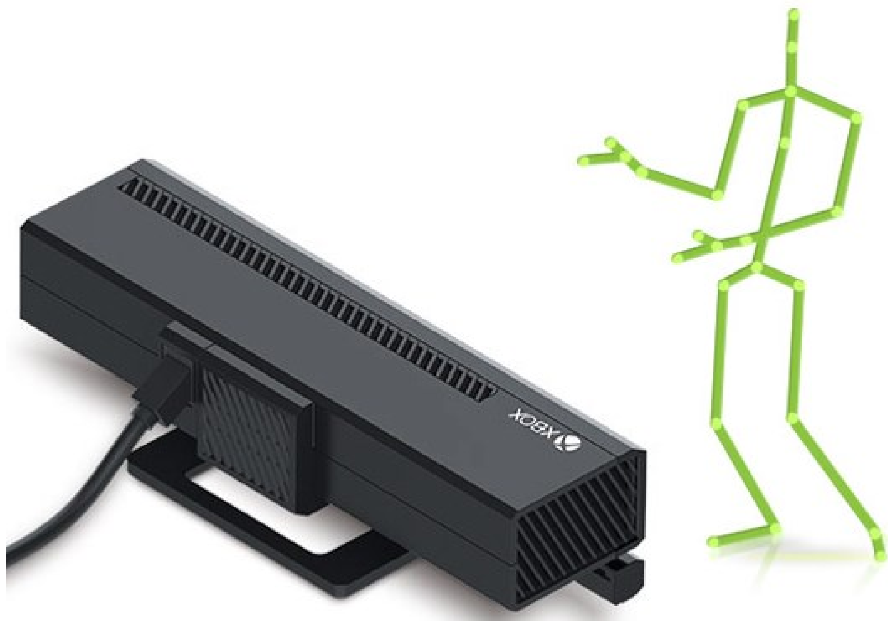


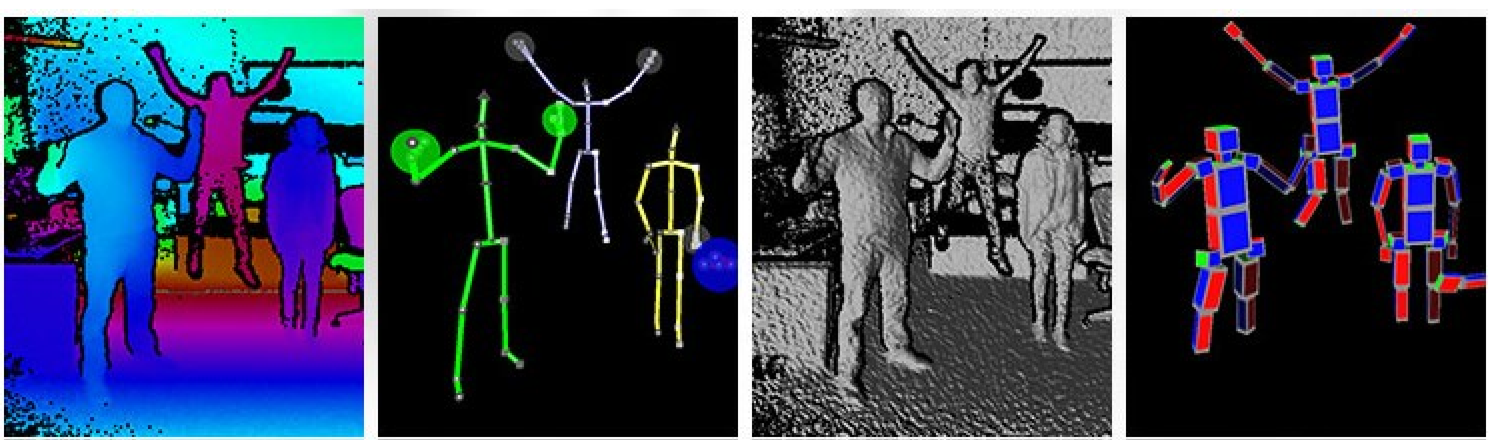
Markerless Systems - Organic Motion



Markerless System – No Markers Needed

Markerless Systems – Microsoft Kinect





Examples in Golf

AMM and TPI

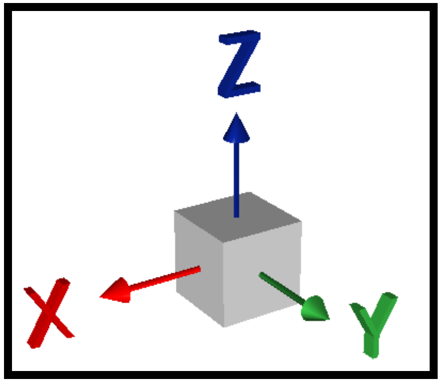
AMM 3D Motion Measurement

- 12 Sensor, 6DOF, Full Body
- Upper Body
  - Head
  - Thorax (Ribcage)
  - Arms and Hands
    - Shoulders, Elbows, Wrists
  - Club
- Lower Body
  - Pelvis
  - Legs and Feet
    - Hips, Knees, Ankles
    - Feet - Stance

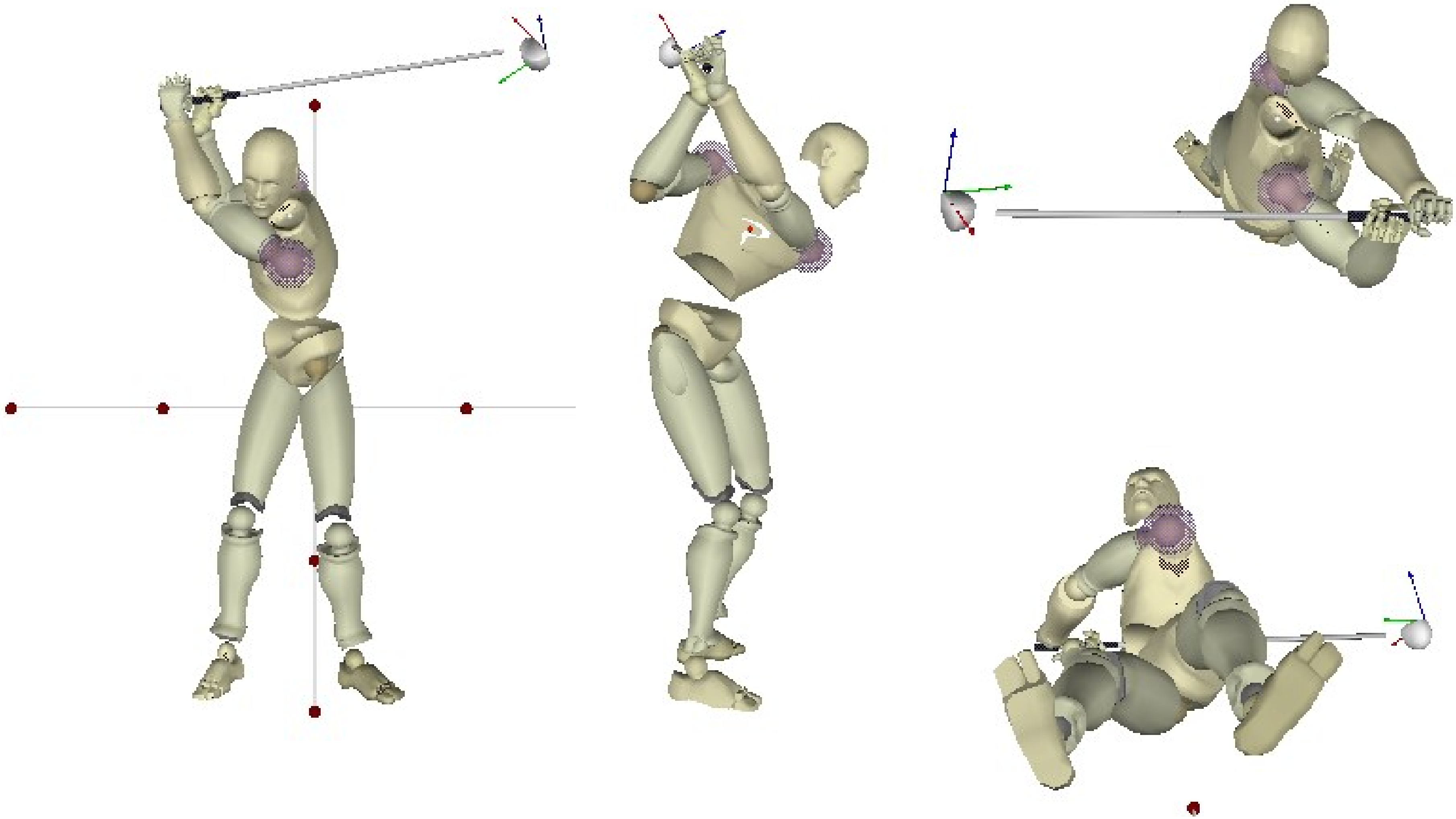
TPI Biomechanics and Database

- TPI 3D Advanced Layout
- Pro Databases
  - PGA
  - LPGA
  - Long Drive
  - Amateur
- Comparative Reports
  - Over 400 values
- Comparison Table
  - Nearly 200 Graphs

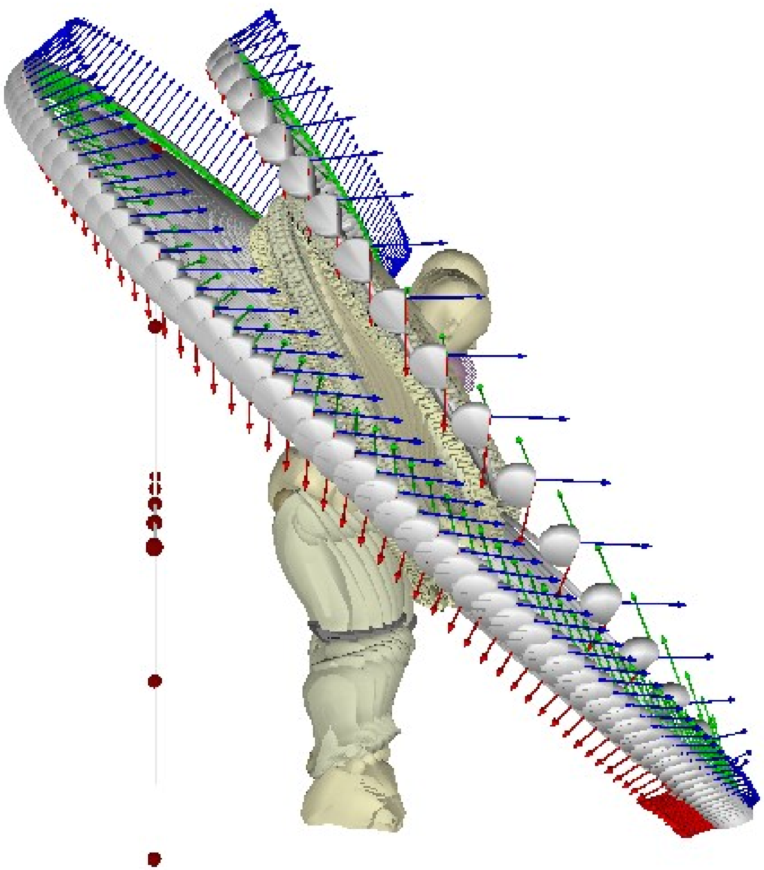
AMM3D Electromagnetic

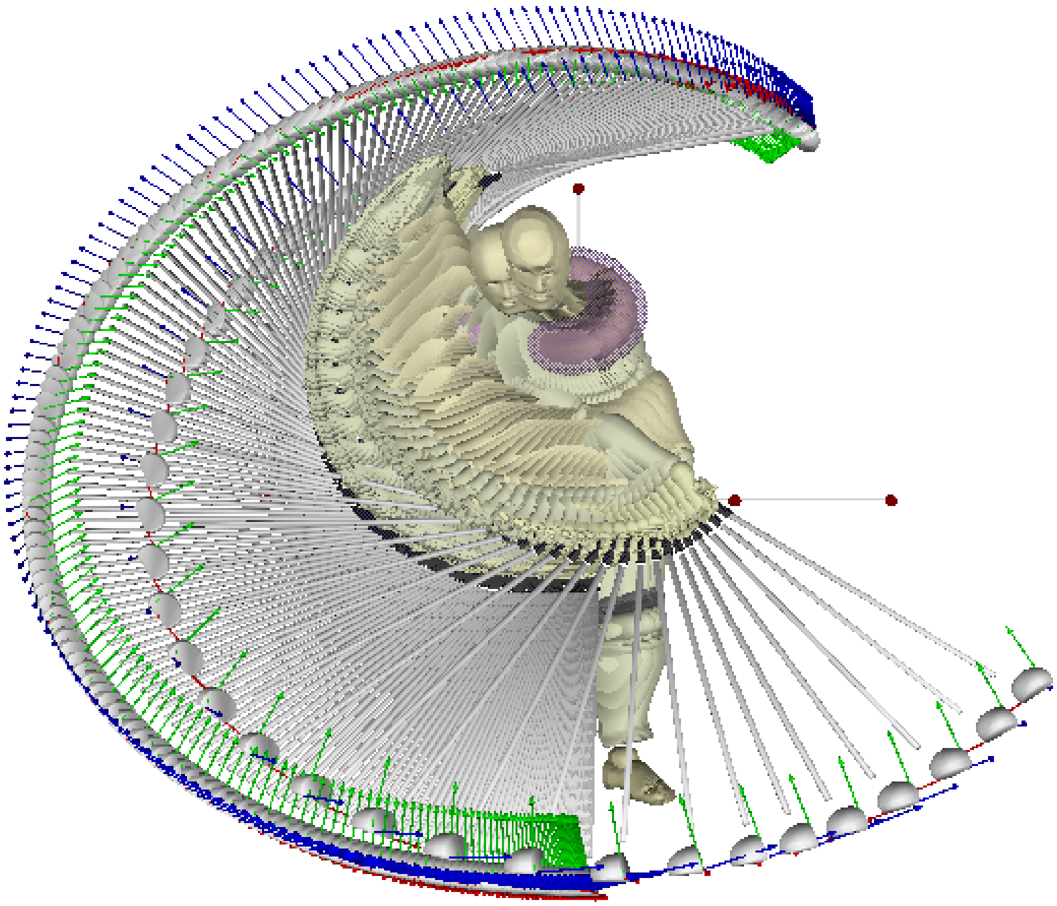


View 3D Image from Any Direction

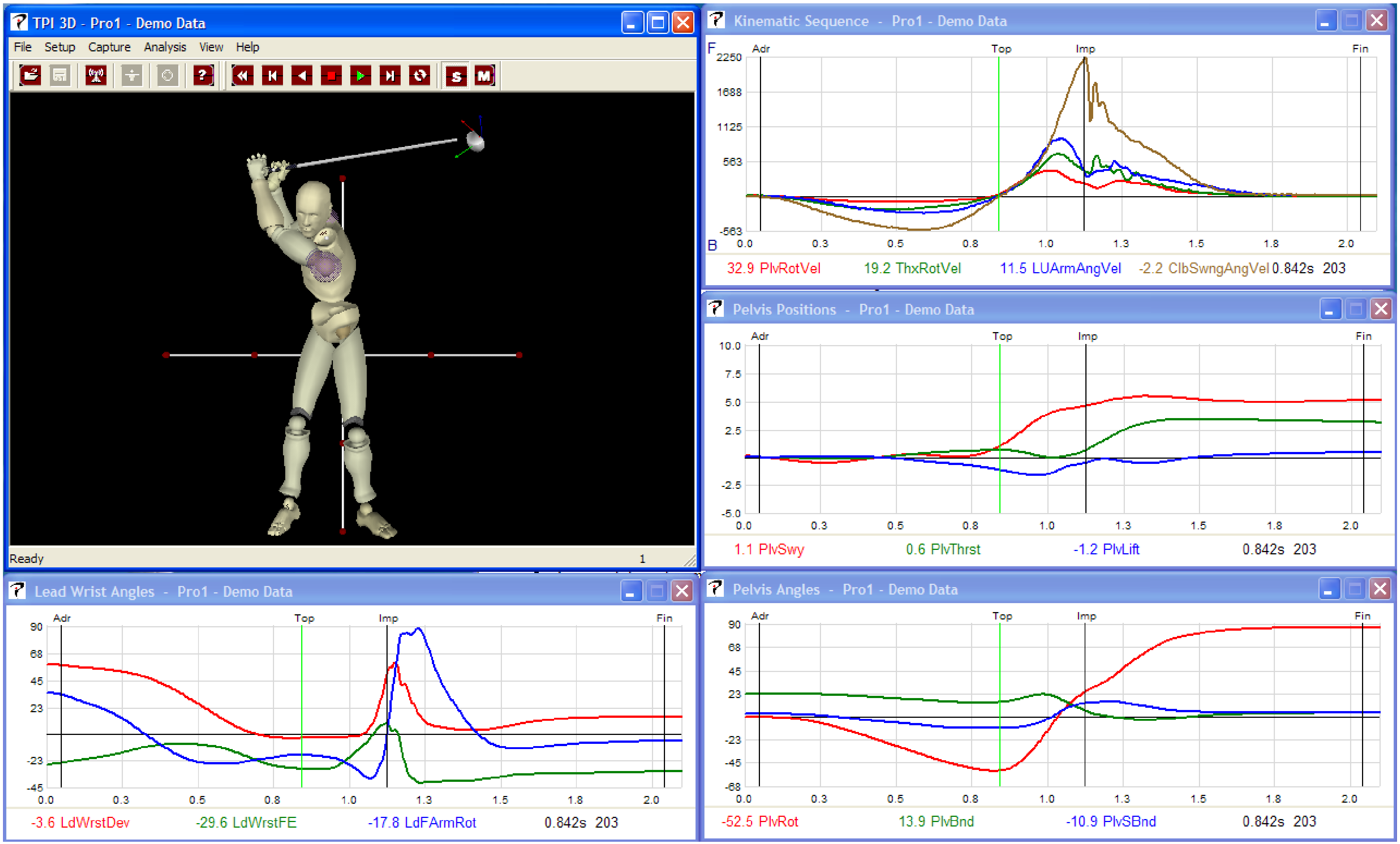


Multiple Mode for Club Plane View





Screen Layouts with Synchronized Graphs



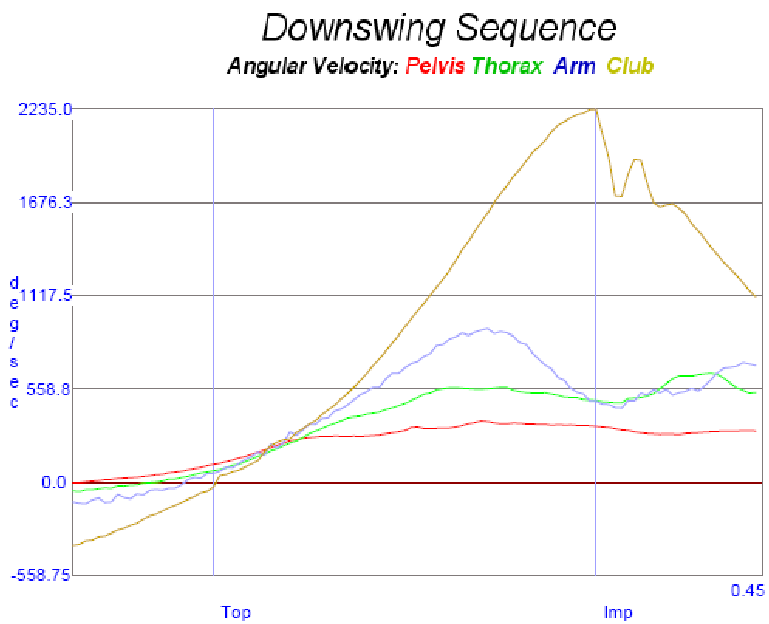
Comparison Table and Database

Data Demo | Pro2 | Positions | 97.8 C to 83.4 C

Parameter	Units	Adr	HB	Top	HD	Imp	HF	Fin
Pelvis Rotation (Open-Closed)	deg	2.5 O	17.5 C	55.8 C	30.4 O	41.4 O	50.6 O	113.2 O
Pelvis Bend (Fwd-Back)	deg	23.8 F	21.4 F	17.2 F	14.3 F	10.0 F	10.4 F	14.5 F
Pelvis Side Bend (Trail-Lead)	deg	0.3 L	3.7 L	8.5 L	11.7 T	12.0 T	10.4 T	7.7 T
Thorax Rotation (Open-Closed)	deg	13.3 O	29.8 C	100.0 C	3.5 O	23.5 O	55.6 O	150.6 O
Thorax Bend (Fwd-Back)	deg	36.3 F	35.7 F	6.6 B	34.3 F	24.1 F	2.5 F	36.5 B
Thorax Side Bend (Trail-Lead)	deg	16.0 T	13.5 L	40.8 L	12.6 T	27.0 T	48.2 T	9.7 T
Pelvis Sway (To-Away)	in	0.0	1.6 A	0.8 A	2.4 T	2.5 T	3.4 T	8.4 T
Pelvis Thrust (Fwd-Back)	in	0.0	0.5 B	1.8 F	2.1 F	2.8 F	3.3 F	2.9 F
Pelvis Lift (Up-Down)	in	0.0	0.0	1.8 D	1.1 U	1.5 U	1.3 U	0.2 U
Thorax Sway (To-Away)	in	0.0	1.4 A	1.2 A	0.0	2.0 A	4.5 A	5.8 T
Thorax Thrust (Fwd-Back)	in	0.0	0.1 F	2.4 F	0.5 B	0.9 B	0.6 B	2.5 F
Thorax Lift (Up-Down)	in	0.0	0.8 D	2.3 D	1.7 U	2.2 U	0.9 U	1.3 U
Spine Rotation (Open-Closed)	deg	11.2 O	13.9 C	47.9 C	27.9 C	20.5 C	5.8 C	31.5 O
Spine (Flex-Ext)	deg	12.5 F	14.3 F	23.8 E	20.0 F	14.1 F	7.9 E	51.0 E
Spine Side Bend (Trail-Lead)	deg	16.3 T	9.8 L	32.3 L	1.0 T	15.0 T	37.8 T	2.0 T
Head Rotation (Open-Closed)	deg	3.7 C	13.7 C	19.5 C	4.5 C	0.6 C	3.8 O	77.4 O
Head Bend (Fwd-Back)	deg	46.3 F	42.3 F	33.2 F	49.1 F	52.0 F	49.8 F	8.8 B
Head Side Bend (Trail-Lead)	deg	1.0 L	9.7 L	10.0 L	6.9 T	8.6 T	11.0 T	29.7 T
Head Sway (To-Away)	in	0.1 T	2.8 A	3.7 A	2.1 A	3.1 A	4.6 A	12.3 T
Head Thrust (Fwd-Back)	in	0.0	0.2 B	0.8 F	0.2 B	0.7 B	0.7 B	2.6 B
Head Lift (Up-Down)	in	0.0	0.5 D	0.2 D	0.5 D	0.3 D	0.7 D	8.2 U
Neck Rotation (Open-Closed)	deg	18.1 C	15.7 O	80.7 O	10.8 C	28.5 C	56.0 C	71.3 C
Neck (Flex-Ext)	deg	10.0 E	6.7 E	39.8 E	14.7 E	27.8 E	47.3 E	27.8 E
Neck Side Bend (Trail-Lead)	deg	17.1 T	3.8 L	30.8 L	5.7 T	18.5 T	37.2 T	20.0 L

Rng: PGA-Driver Prj: Full Body 12R TPI 7-14-04

Comprehensive Biomechanics Report



Sequence Parameters

		Pelvis		Thorax		Arm		Club	
Peak Order	order	1		3		2		4	
Peak Timing Pre-Impact	ms	75	77 to 113	63	54 to 89	71	62 to 81	0	-1 to 5
Peak Speed	d/s	367	415 to 522	570	629 to 764	920	888 to 1038	2233	2108 to 2306
% of Max	%	16	18 to 23	26	28 to 34	41	40 to 46	100	100 to 100
Acceleration	d/s/s	1405	1717 to 2595	2496	2579 to 3856	4873	4190 to 5942	9043	7474 to 9734
Deceleration	d/s/s	420	1223 to 2734	1279	1508 to 3889	6129	5764 to 8356	9537	7821 to 9375

Segmental Interactions

		Pelvis-Thorax		Thorax-Arm		Arm-Club	
Time Between Peaks	ms	13	5 to 43	-8	-18 to 17	71	61 to 79
Angular Speed Gain	d/s	203	184 to 272	350	211 to 321	1313	1160 to 1327
Gain Factor	ratio	1.6	1.4 to 1.6	1.6	1.3 to 1.5	2.4	2.2 to 2.4

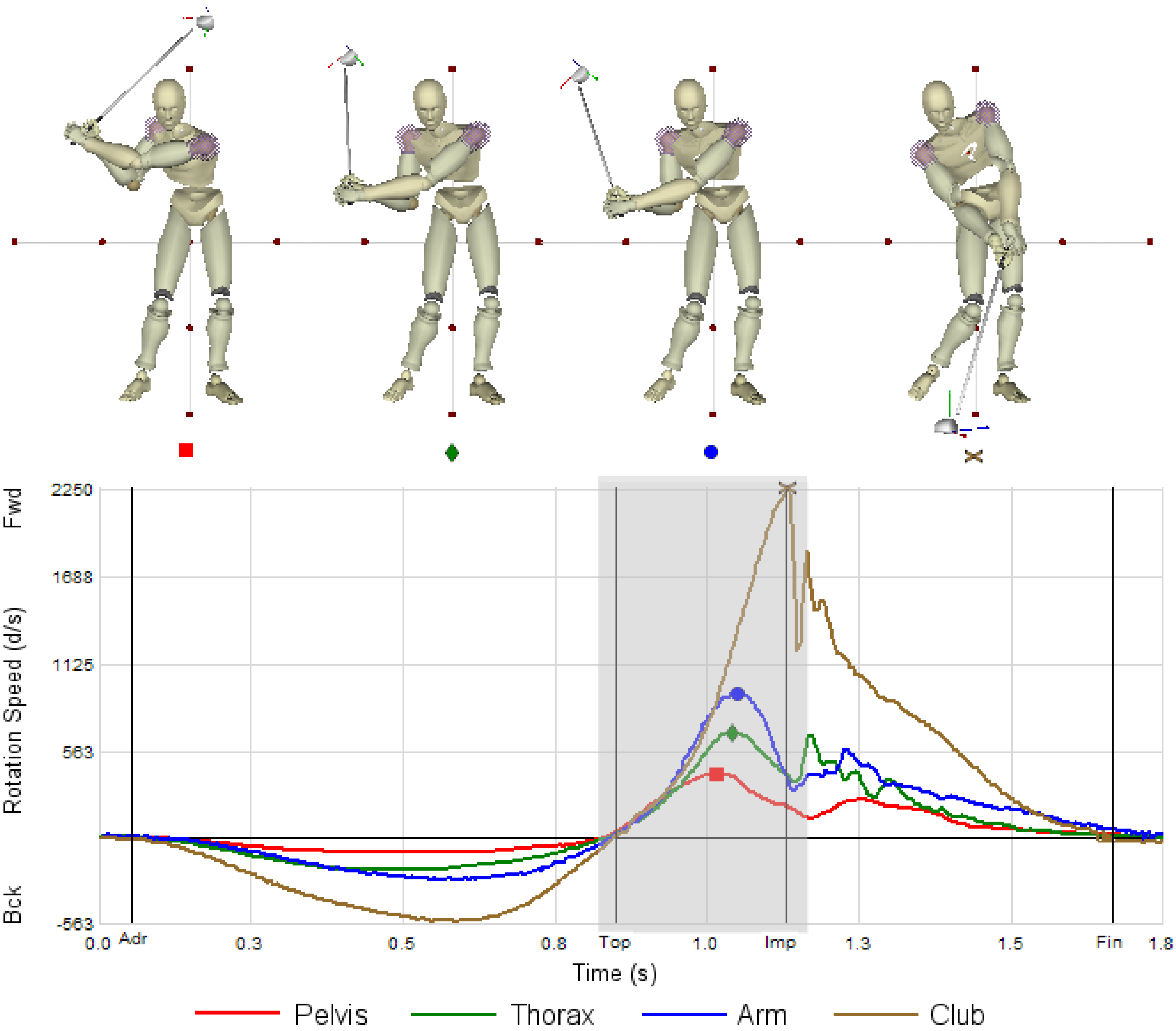
Contribution by Joint

		Legs		Core		Shoulder		Wrist	
% Contribution	%	16	18 to 23	9	8 to 12	16	9 to 14	59	53 to 59

3D Motion Biofeedback

- Real-Time Audio Feedback of Position and Motion Accelerates Learning
- Student Learns to Recognize the Correct Posture and Motion
- Makes Feel Become Real
- Avoids Grooving Incorrect Repetitions
- Automatically Monitors Correctness of Drills, Exercises and Physical Screens
- Helps Implement Effective Block and Random Training where Appropriate

The Kinematic Sequence



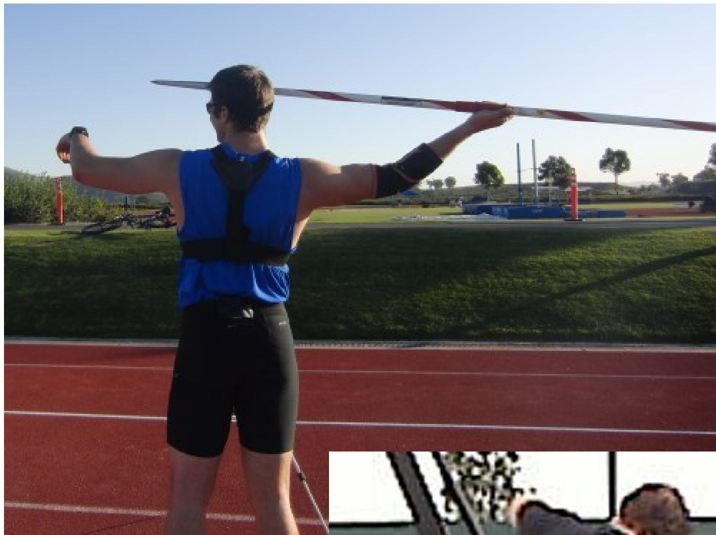
Motion Analysis at the Olympic Training Center in Chula Vista

Wireless Inertial Sensors

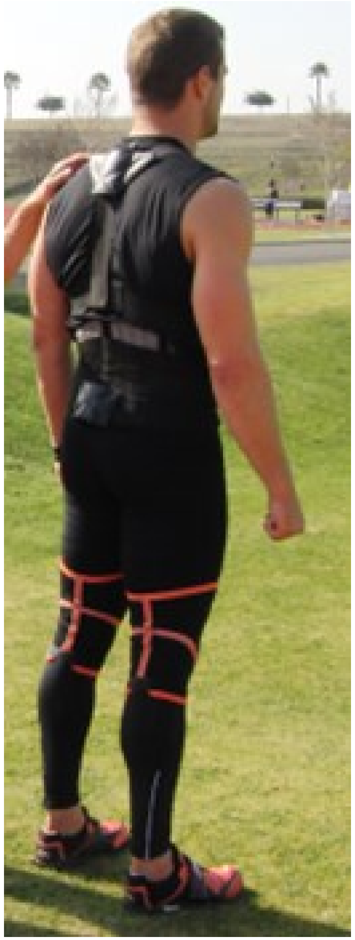
- Practical and Easy
- Hips, Shoulders, Arm
- AMM Inc. AmmSensors
- Bluetooth Wireless
- Fast – 250 samples/sec
- Small, Light Weight
- Immediate Report
- Simultaneous Video

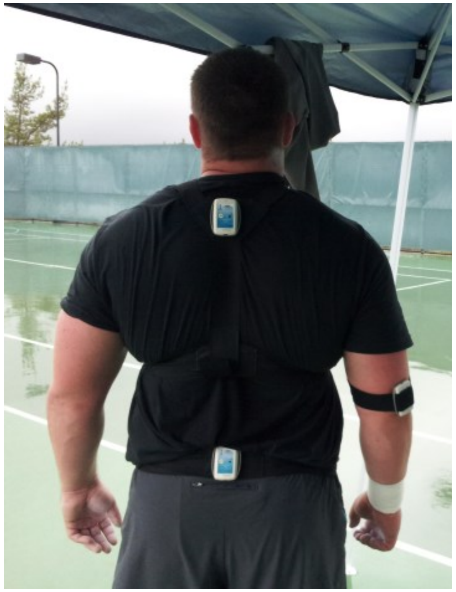
- Angles Only

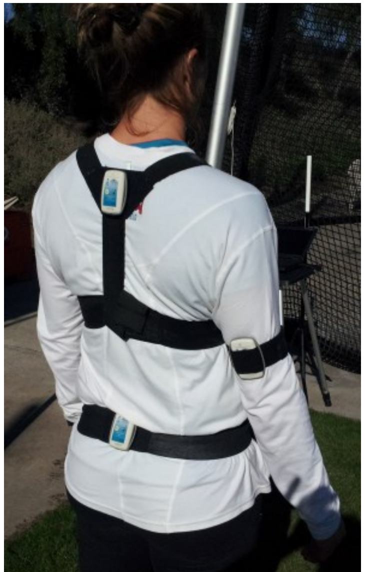
Discus, Javelin, Shot, Hammer



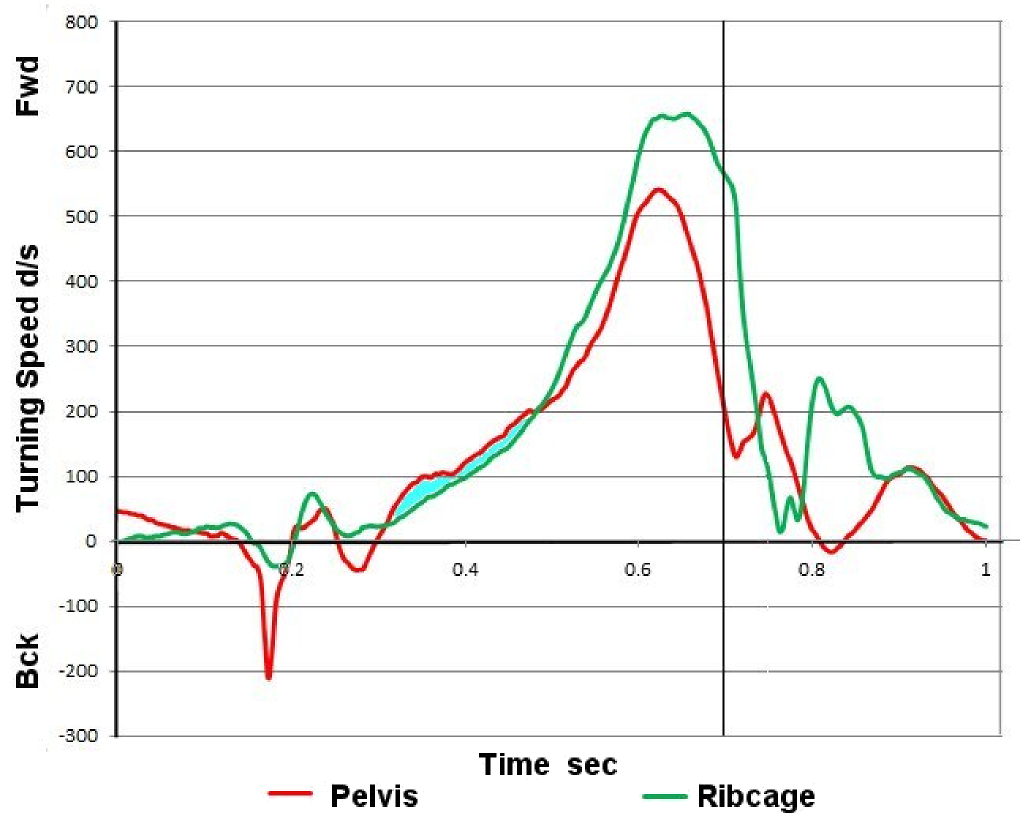
Discus, Javelin, Shot, Hammer







Kinematic Sequence - Javelin



- Separation (X-Factor)
- X-Factor Stretch (Stretch Shorten Cycle)
  Finger Snap Demo
- Sequence and Timing

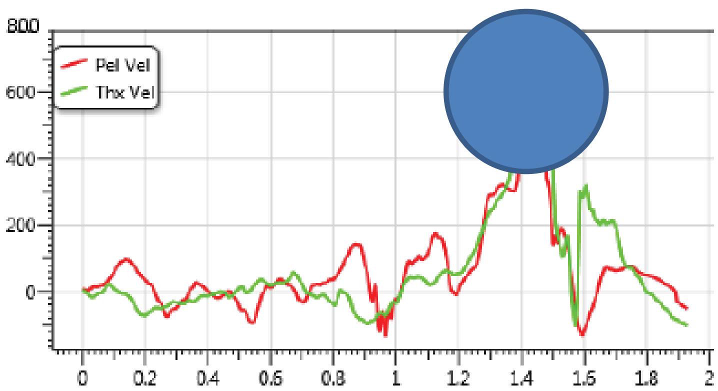
- Max Turning Speed
- Speed Gain
- Average Acceleration
- Average Deceleration

Javelin Workshop

- Three athletes used the sensor
- Enjoyed using it
- Were able to make changes

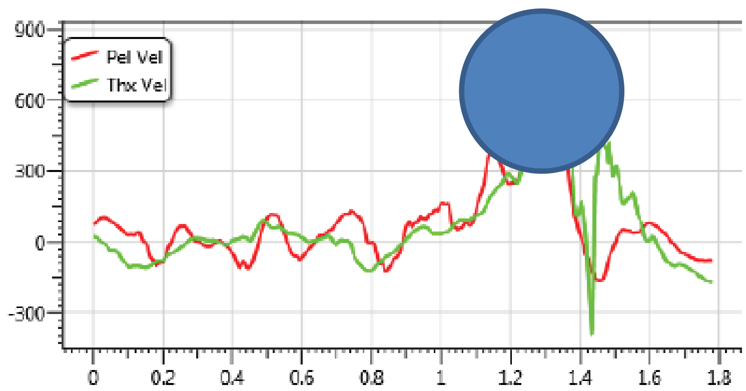
Example Athlete - Javelin

- Initially had minimal speed gain (red and green peaks almost the same in first graph)
- After working with Coach he was able to gain speed from Pelvis to Thorax (Red to Green)
- We did not measure the throw distance



Angular Velocities (deg/sec)

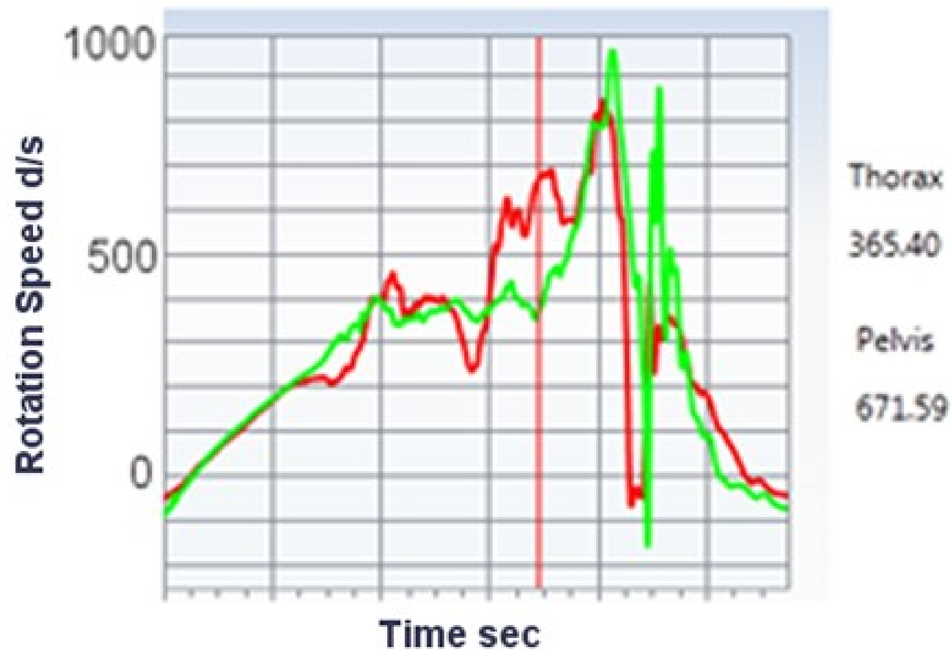
Parameter	Value
Peak Pelvis Angular Velocity	738
Peak Thorax Angular Velocity	741
Angular Speed Gain	4



Angular Velocities (deg/sec)

Parameter	Value
Peak Pelvis Angular Velocity	699
Peak Thorax Angular Velocity	870
Angular Speed Gain	171

Kinematic Sequence - Discus

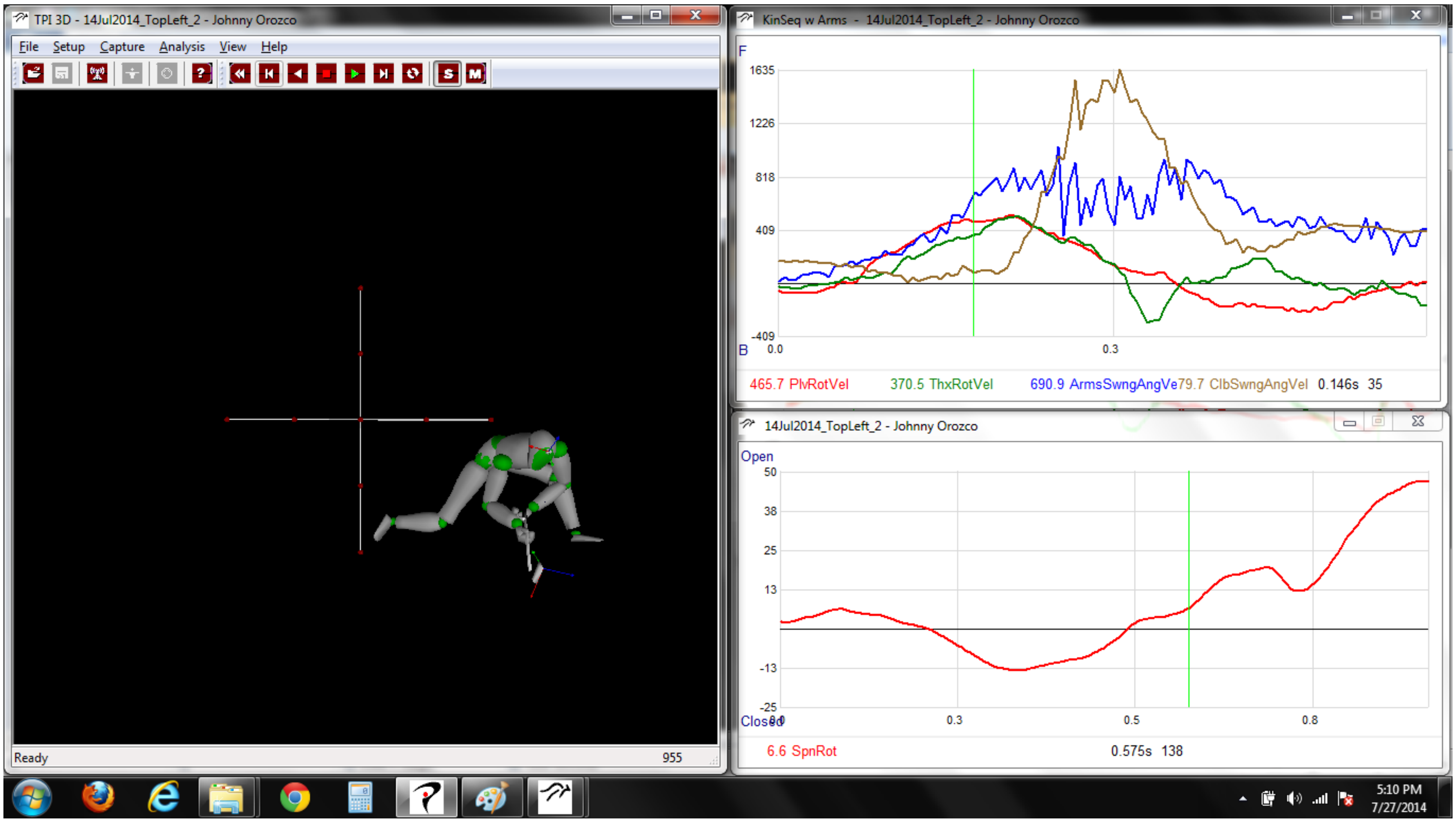


Full Body Capture with Electromagnetic System

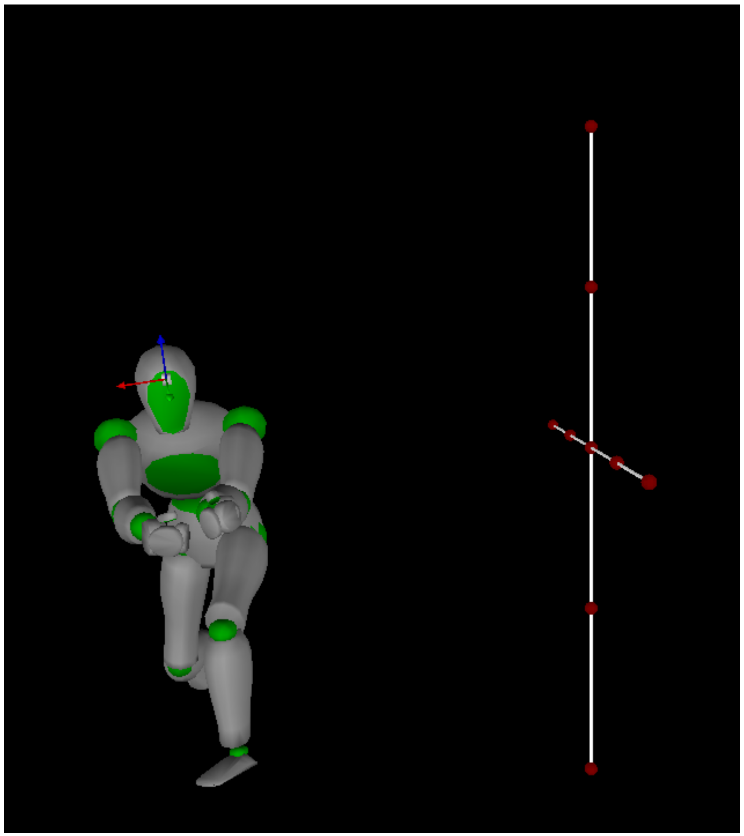
Field Hockey and Rugby

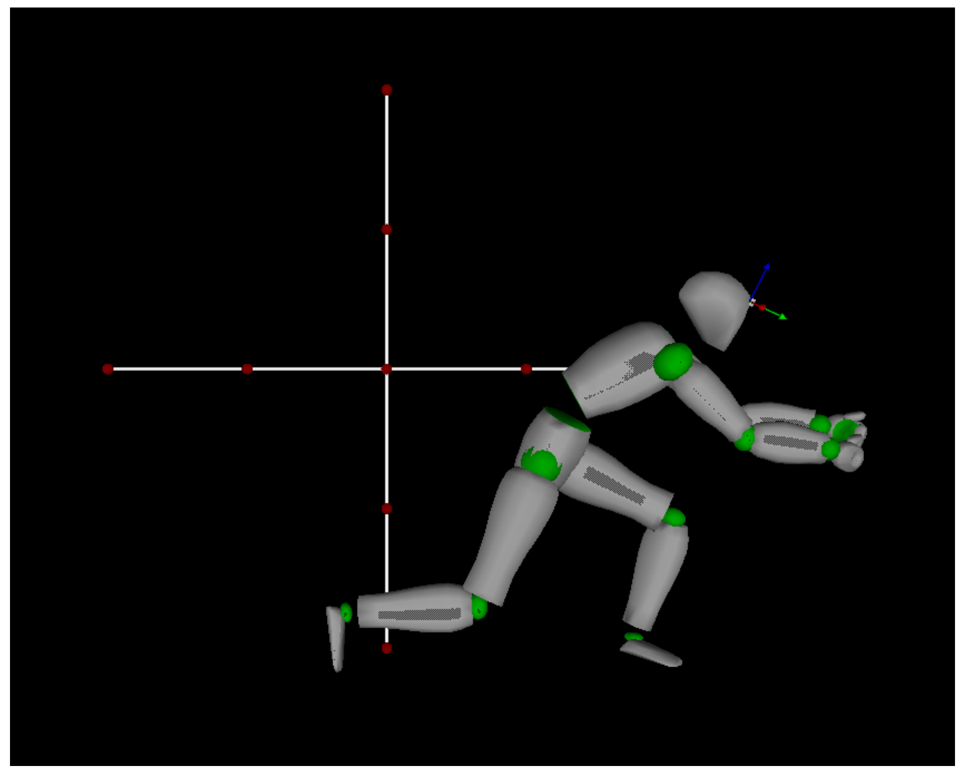

USA

Drag-Flick


TPI 3D - 14Jul2014_TopLeft_2 - Johnny Orozco
File Setup Capture Analysis View Help
Ready
955
KinSeq w Arms - 14Jul2014_TopLeft_2 - Johnny Orozco
F
1635
1226
818
409
-409
B
0.0
0.3
465.7 PlvRotVel
370.5 ThxRotVel
690.9 ArmsSwngAngVe
79.7 ClbSwngAngVel
0.146s 35
14Jul2014_TopLeft_2 - Johnny Orozco
Open
50
38
25
13
-13
-25
Closed
0.0
0.3
0.5
0.8
6.6 SpnRot
0.575s 138
5:10 PM
7/27/2014

3D Motion – Scrum-Half Pass





Women's Rugby 3D

- Scrum-Half Pass
- Interested variables include:
  - Foot placement
  - Body position before, during, and after pass
  - Rotation/rotational speeds
  - Resultant velocities of pelvis, thorax, and hands
  - Arm/wrist action
  - Timing

System of the Future

- Inside
  - Probably a combination of
    - Camera based, markerless tracker
    - Inertial Sensors
- Outside
  - Comfortable wearable suite with combination of sensors
    - Inertial, local GPS

End

Thank You