3D Golf: The New Frontier of Golf Swing Analysis

Featuring Contributions by Noted Golf Biomechanics Industry Leaders including ......

**Phil Cheetham**: Founder of Advanced Motion Measurement (AMM)

**Michael Bentley**: creator of the K-Vest, Co-Founder of Blast Motion, Inc.

**Tim Suzor**: K-Vest Certification Team Leader, co-Founder of Kinetic Golf 360

**Dr. Robert Neal**: Founder of Golf BioDynamics

Published by Nick Chertock
Founder of GolfProgress

“Exploring the Golf Improvement Process”

[www.golfprogress.net/3D](http://www.golfprogress.net/3D)
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**Golf Biodynamics**

Swing excellence through 3D technology

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**Amm**

Advanced Motion Measurement

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**Golf Progress**

3D Golf: The New Frontier of Golf Swing Analysis

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www.golfprogress.net/3D
Insights from Scientists and Coaches who use 3D golf analytical systems

From a Technical Innovator

Michael Bentley, Founder of Blast Motion

From the Academics

Dr. Mike Duffey, and Eric Handley, Penn State University

From the Teaching Professionals

Pete Cunningham

Tyler Ferrell

Jon Sinclair

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Derek Hooper

Resource Page
Since 2002, K-MOTION Interactive (KMI) has been an industry leader in the field of 3D motion capture technology. From swing capture to range of motion and biofeedback systems, their technology is now used in every major U.S. city and country around the world. As the developer of the industry's most popular and innovative suite of motion capture products and services, KMI's mission is focused on intuitive and easy-to-use solutions that accurately measure motion and improve physical performance.

http://www.k-vest.com/

**KVEST Certification Team**

**Tim Suzor**  
CEO at Thinq Sports and Managing Parter at K-Vest. Tim has been a PGA teaching professional since 1995. In addition to Thinq Sports and KVEST, Tim is a TPI-Level 3 Golf Fitness / Biomechanics Instructor and a member of the K-VEST Certification Team. Tim has specialized in biomechanics and golf fitness for over a decade and is also highly committed to teaching the mental aspect of peak performance. Kinetic Golf 360 is the performance center in Scottsdale, AZ where Tim works with his clients.

**Tony Morgan**  
Tony is a Class A PGA professional with over 14 years of experience in sales, business management, marketing, and instruction in the golf industry. He is responsible for overseeing K-Motion Interactive, Inc's rapidly expanding sales and marketing division, including implementing programs and services to drive national awareness regarding the importance of swing efficiency and 3D technology. In 2008, he facilitated an on-going relationship between KMI and the Titleist Performance Institute.

**Cory Puyear**  
Cory is the co-director of certification for K-Motion Interactive. As a licensed physical therapist and certified strength and conditioning specialist, Cory has dedicated his career to understanding the biomechanics, manual therapy, rehabilitation and restorative exercise as they relate to golf. Cory has been a consultant for many golf schools and has appeared on The Golf Channel as a golf fitness expert. Cory has been certified as a golf fitness instructor -Medical level 3 Junior Level 3 and Golf Biomechanist level 2 through the Titleist Performance Institute. Cory is also a certified FMS practitioner. He lectures to fitness and golf professionals around the country on the benefits of 3D motion analysis and biofeedback.
Golf Progress Commentary:
The K-Vest is the most widely available 3D motion capture product on the market and was my first introduction to motion analysis. The wireless nature of the jacket combined with the auditory feedback available has helped thousands of teaching professionals and players to improve. ~Nick Chertock

K-VEST - A Little History

Since 2004, K-Motion Interactive (KMI) has focused on developing easy-to-use solutions that accurately measure a golfer’s motion and provide a road map to improve performance. KMI’s flagship technology, K-VEST, is the most widely used 3D system in the golf market today.

To understand why 3D technology is becoming so popular with both coaches and their players, is to fully understand the evolution of the technology within our industry. As teachers, instructors, and coaches know, we have been using our eyes to analyze the motion since the inception of golf over 600 years ago. Some of the game’s greatest teachers visually analyzed a golfer’s motion and verbally conveyed, or demonstrated, a potential solution to improve ball flight. The human eye, which can see motion effectively at 12-15 frames per second, allowed us to see some of the key positions of the player's swing, but was limited to what a the human brain can actually observe and recall. When video technology was introduced, it allowed professionals to slow down the motion so we could see what our eyes might have missed. It was an advancement that greatly improved analysis, allowed both instructors and students to better identify swing faults, and help correlate those faults to ball flight. The problem with video, then and today, is that the motion analysis is subjective and based an instructors’ methods and processes.

Then came the advancement of 3D technology within the golf industry. K-VEST introduced us to small, wireless sensors placed on the golfer's pelvis, upper body and lead hand. The advancement in this technology allowed professionals to move the analysis from style to efficiency of the motion, almost instantly. What does this mean? It meant that there's a new and improved way "to look" at a golf swing and determine what changes need to be made to improve a player's accuracy, distance, and overall ball striking abilities. More importantly, it is not subjective to a teacher's eye or teaching style. This new information would be the catalyst behind K-VEST’s swing efficiency education and training programs that have now certified over 500 professionals worldwide.

Education

In our commitment to moving the bar in education, K-Motion Interactive has assembled an advisory board that includes 16 of the world's top golf, fitness and medical professionals. This K-VEST Advisory Board oversees the development and protocols for our rapidly expanding swing efficiency certification program.

The K-VEST team is fully committed to embracing the advancement of motion capture technology and innovative software applications; however, advancing education has always been, and will continue to be,
one of the company’s major initiatives. We understand that 3D technology, such as K-VEST, is only as good as the instructor using it, which is why it is our goal is to help professionals more effectively understand 3D data, while providing practical solutions that improve performance in less time, and with minimal stress on the body.

K-VEST currently offers two levels of certification that provide professionals with interactive training on 3D motion capture technology. Accredited by the PGA of America, the curriculum is designed to help professionals not only understand 3D motion, but also effectively communicate the information to their players.

Understanding this information, along with the forces that create the motion, is a major component of the K-VEST certification program. There are many organizations and universities around the world focused on collecting data with multiple sensors and highly sophisticated technology. In an ever expanding world of information, we believe that it comes back to the ability to interpret the data and provide solutions that help players accomplish their goals.

**How does K-Vest help the student?**

There are three basic learning styles: visual, kinesthetic, and auditory. Effectiveness of each style will vary from player to player. However, using all three simultaneously, as K-VEST’s biofeedback training does, allows students to learn new motions and motor programs faster than we ever thought possible.

The best teachers in the world know how to effectively message to his or her students what exactly needs to be done to improve performance. However, students often have a difficult time taking what they have learned in a lesson to the course, or even continuing to practice correctly outside the supervision of an instructor. A student using K-VEST’s biofeedback training is like having an instructor continuously giving you feedback 180 times per second. Plus, a student can perform the biofeedback training with or without the presence of an instructor.

Additionally, 3D biofeedback training allows for more self-discovery, less coaching, and it follows the model on how we learn: knowledge, instruction, and feedback. The training breaks neurological governing patterns that get hardwired over time.

The days of beating balls and creating muscles imbalances and injuries are dissipating with more efficient training programs. K-VEST’s new K-TRAINER software allows instructors to build customized programs based on individuals’ movement patterns. Programming sets, repetitions, and hold times are just a few of the features that allow students to train more efficiently.

In the spring of 2012, the K-VEST Certification Team presented its research at the World Scientific Congress of Golf Seminar, which identified some proven benefits of biofeedback training using K-VEST. Specifically, the study looked at how training only pelvis bend, rotation, and side-bend improved the kinematic sequence, and as a result, club speed.

During the study, K-VESTs certification measured the swing patterns of two groups: an experiment group and a control group. Both groups were subjected to two rounds of testing. However, the
experiment group had conducted six, 30-minute biofeedback-training sessions in the K-VEST between the two rounds of testing. The team looked at how biofeedback training effected pelvis movement (bend, rotation, and side-bend), transition sequence, peak speed sequence, acceleration/deceleration patterns, and peak rotational velocities. The end result was an 11.7% increase in club velocity.

**Misconceptions about 3D in Golf.**

Despite K-VEST’s focus on easy-to-use, practical solutions and its robust education programs, many still hold deep-rooted misconceptions about 3D motion analysis in golf. One of the most common misconceptions is that those using 3D technology subscribe to a teaching philosophy, or style. That, however, couldn’t be further from the truth. 3D technology simply allows users to record and identify, scientifically, the efficiencies and inefficiencies in a player’s swing. By identifying these inefficiencies, instructors can quickly determine the root cause of a player’s swing fault, and offer corrective exercises to fix the identified fault, regardless of swing style or philosophy. Additionally, the corrective exercises can be measured using the 3D technology to determine its effectiveness.

Another common misconception is that 3D analysis systems can be cumbersome and difficult to use. It’s understandable, since prior to K-VEST, 3D systems consisted of a web of wires and sensors designed for research purposes, and were used primarily by scientists and institutions. Thus, they’re cumbersome and difficult to use. However, the K-VEST was designed by golf instructors to be used by golf instructors. Designers focused on intuitive, golf-friendly software, wireless sensors, and the ability to use indoors or out. Now, with advancements in wireless, self-contained sensors, intuitive software applications, and educational support, integrating 3D motion capture has never been easier.

**What does the future hold for 3D golf analysis?**

3D motion systems will continually become more popular and valuable in golf. Already, most of the world's best instructors use 3D because of its ability to quickly improve a player’s performance. Next-generation 3D technologies will utilize smaller, faster, and less expensive sensor technology. Applications will continuously become easier to use while software will be deployed on new, portable devices. Education, research, and knowledge will continue to expand as analysis systems integrate everything from video, to ball-flight data, to ground-force measurements.

Watch [Mark Blackburn](http://www.youtube.com/watch?v=LPU7sKsSMqQ) and tour pro Heath Slocum working with the K-Vest at the 2011 U.S. Open.
Dr. Robert Neal

Dr. Neal completed his PhD in Biomechanics at the University of Queensland Australia in 1988. His honors thesis was the world’s first on 3D kinematic and kinetic analysis of the golf swing. Dr. Neal co-founded Golf BioDynamics (GBD) in 2000 to provide expert 3D golf swing analysis to the golf instructor and golfer. Dr. Neal is a consultant to TPI, the Australian Institute of Sport, Jim McLean Golf Schools, numerous college golf teams and international touring players.

http://www.golfbiodynamics.com/

Golf Progress Commentary:
Dr. Neal has established Golf BioDynamics as the leading 3D solution in Europe and Australasia and in 2003 developed a strategic alliance with Jim McLean at Doral Resort & Spa in Miami, FL. He is regarded by many in the field as the world's foremost golf biomechanist.

Golf BioDynamics: Swing Excellence Through 3D Technology
by Dr. Robert Neal

1. What is the significance of 3D technology for the golf teaching field?

The significance of 3D technology has yet to be fully realized in the golf teaching field because so few coaches have actually invested in learning about the technology and how it can assist in the development of golfers’ swings. While there are a few really dedicated professionals who are always looking for ways in which to improve the learning experience of their students, I would say that the majority of golf instructors are ignorant of 3D measurement and feedback systems.

3D technological tools are valuable for the coach to be able to quantify technique and then give feedback to the player. They also allow for complete “analysis” of the swing so that strengths and weaknesses in technique can be identified. It goes beyond the visual representation of a golf swing that is available with video. Another interesting aspect about 3D is that you can garner insight into the physical capabilities and limitations of the golfer (e.g., dynamic stability, flexibility, coordination, efficiency, power, etc.).
Lastly, the use of biofeedback in bringing about movement pattern change is huge yet few people have utilized this aspect of 3D technology to its fullest.

2. **How does your product help an instructor teach more effectively?**

The GBD technology really aids the golf coach in the following ways:

2.1. It quantifies the golfer’s technique (analysis)

2.2. It was designed specifically for golf, golfers and golf coaches so the reports present the information in a meaningful yet simple way

2.3. Reports can be generated for one or multiple swings with different clubs

2.4. It has been integrated with TrackMan so that the instructor can see how changes in the biomechanics affect both club deliver and ball flight

2.5. Auditory biofeedback is available on over 60 variables

2.6. Visual biofeedback is available through the 3D animation. There is the option to hide/show body segments so that it is easier for the player/coach to visualize the swing.

2.7. Many different charts are available for each swing (e.g., timing sequence, transition sequence, take-away sequence, hip and head sway, X-Factor, rate of stretch/recoil, etc.)

2.8. Critical events are automatically calculated by the software and the animation/display can be moved to these events with a single keystroke (e.g., hit A for address or I for impact)

2.9. Reports can be emailed directly from the software to save time for the instructor

2.10. There is the ability to easily add commentary to the report after it has been generated

2.11. Screen dumps (print screens) can be generated to help illustrate a change/issue for the student (these can be printed or emailed)

2.12. Swing files can be sent to the player and they can download a free version of the software for viewing the swings and creating reports, etc.

2.13. Two windows within the software can be opened simultaneously so that comparisons can be made (with a good player or before/after scenarios). Swings can be synced at impact (or any other event)

2.14. The platform is VERY stable and will run on all versions of Windows. Minimum processor is a dual core one.
2.15. Animation is available in real-time, with TrackMan and with biofeedback running (i.e., all processes running on the one computer).

2.16. It helps the coach prioritize the areas that need to improve

2.17. The system can be used for short game (Putting and Pitching) as well as for the long game (irons and woods)

3. How does your product help improve the student’s learning experience?

3.1. It provides them with a quantifiable and objective measurement of their technique

3.2. It provides them with a plan for improvement and a way of measuring accurately and objectively whether change is occurring and in the right directions.

3.3. Visual and auditory biofeedback can be used to help the golfer understand what it must FEEL like to move correctly

3.4. The biofeedback is the key. When an instructor uses the feedback along with good teaching principles, learning can be accelerated and retention of motor patterns improved. The ability to provide real time feedback on POSITION and ORIENTATION is crucial! Immediately after a swing, reports can be generated or graphs produced (e.g., timing sequence, speeds, etc.)

3.5. It forces them to slow down and practice with purpose (not just beat balls!).

4. What products and services does your company offer?

We offer a range of products including:

4.1. Ultimate System - this system is our complete, high speed system which has up to 8 active sensors (typically 6 or 7). There are multiple models available with this system (Standard Model {6 sensors; hand, forearm, arm, head, UT and pelvis}, Club & Body Model {7 sensors; club, hand, forearm, arm, head, UT and pelvis}, Upper Body Model {8 sensors; both hands, forearms, arms, head, UT and pelvis}, Club & Upper Body Model {8 sensors; club, both hands, forearms, arms, head, UT and pelvis}, Putting (same sensor configuration as Club & Body) and Pitching (can use Standard, Club & Body, Club and Upper Body and Upper Body models). Reporting system is built in, biofeedback is included, integrated with TrackMan, etc.

4.2. Biofeedback System - This system is designed for biofeedback training. It has only two sensors but these can be used in multiple locations. Real-time animation is available as well as simultaneous video capture (i-camera). System can be operated by the one person (i.e., the golfer can calibrate the system himself, set biofeedback ranges and work alone). A snap calibration method is used but then standard transformations are applied to make the coordinate systems
match with the Ultimate System, anatomical coordinate systems and the biofeedback ranges match too. The models available include:

4.2.1. Pelvis and Upper torso
4.2.2. Upper torso and Head
4.2.3. Pelvis and Head
4.2.4. Upper torso and lead arm
4.2.5. Lead arm and lead hand
4.2.6. Pelvis and club
4.2.7. UT and club
4.2.8. Head and club
4.2.9. Lead arm and club

4.3. Hybrid System - this system is under development and is based on the latest semi-wireless system produced by Polhemus (www.polhemus.com), the G4. We will have three different systems depending on the number of active hubs. The first will be primarily used for biofeedback training whereas the other two will be more like the models available in the Ultimate System.

We also offer a range of services including:

1. Seminars (education for golf professionals)
2. 3D services at private clubs (i.e., we will come to your club to work with your professional and the members)
3. Training for National Teams and elite golfers
4. Packages at our locations

5. **What are some of the misconceptions surrounding 3D technology applied to golf?**

Typical misconceptions include:

5.2. The numbers are confusing
5.3. There is too much information
5.4. It is not necessary (just dig the answers out of the ground!)
5.5. The sensors are uncomfortable to wear

5.6. Your swing is different when using the sensors

5.7. The systems can only be used indoor in a studio

5.8. They are very expensive (some are but others are reasonably priced)

6. Where do you see 3D golf heading in the near future?

As technology improves and wireless transmission systems get better and better, then the use of 3D systems in golf swing instruction will become more commonplace. I can imagine that in the future (at least for the professionals), there could be real time markerless/sensorless 3D linked with TrackMan so that we could see what golfers do on the golf course (and compare that to what they do on the range!). Our Hybrid system is heading that way so that we can find out how someone moves on the course compared to on the range.

Golf Biodynamics introduction with Jim McLean and demonstrations from Dr. Robert Neal

Part 1

http://youtu.be/l4Kjfc-9kgk

Part 2

http://youtu.be/cKO9YiEc-R1
Phil Cheetham
Phil has been an innovator in sport biomechanics for nearly 30 years. He co-developed one of the first sports motion analysis systems while working as Head of Engineering Technology for the US Olympic Committee’s Sport Science Program in Colorado Springs in the early 1980’s. Since then he has co-developed several motion analysis systems for companies he has co-founded, including; Peak Performance Technologies Inc., Skill Technologies Inc. and Advanced Motion Measurement Inc (AMM). Since 2004, Phil has also been working with Dr Greg Rose and Dave Phillips at the Titleist Performance Institute in Oceanside, California as Head Biomechanist and Director of the TPI Biomechanics Advisory Board. Phil co-developed TPI 3D which was formerly AMM 3D. It’s a motion analysis system specifically designed to measure golf swing motion and efficiency using a respected biomechanics principle called the Kinematic Sequence. Today Greg Rose and the team at Titleist call Phil “The 3D Guy” because of his innovation in three-dimensional motion measurement which has proved to be invaluable in rapidly improving athletic performance.

http://www.advancedmotionmeasurement.com/

Golf Progress Commentary:
Phil Cheetham, through his work at Advanced Motion Measurement, has developed the most widely used 6 degrees of freedom tools, which allow the teacher and player to view the swing from various angles and see bend, tilt, and rotation, but also translation, i.e. movement in space. I recently had the opportunity to view my own golf swing using the AMM/TPI3D system at Terry Rowles’ studio in San Francisco (http://www.sfgolfpc.com) and it is a spectacular tool for golf swing analysis. See Page 46 for a partial list of certified specialists.

Analyzing the Golf Swing in 6 Degrees of Freedom
AMM 6DOF Systems
Phil Cheetham, June 2012

What is 6DOF?
Six-degrees-of-freedom (6DOF) means you can move six ways; forward/backward, left/right, up/down; these movements are linear, determine your position and are measured in feet, inches, meters etc. You can also turn, plus bend forward/backward or side to side; these movements are angular, determine your orientation and are measured in degrees.

When you measure something you first need to measure it from something else; that “something else” is called the reference point or reference frame and is considered the (0, 0, 0) point. You can measure any other point from that point by going forward, sideways and up; or, of course backwards, sideways and
down and in any order. As I said earlier, these movements are measured in feet, inches, meters, etc. These three-dimensions account for three of the 6DOF we are discussing.

Once you have moved to that position by moving in three-dimensions, you can change your orientation and bend forward, sideways or turn; orientation is measured in degrees. These are another three degrees of freedom. So the three position movements and the three angle movements make up the 6DOF.

6 Degrees of Freedom

- **Movement Along an Axis (3DOF)**
  - Along the Side-to-Side Axis
    - Sway/Side: Toward-Away
  - Along the Front-Back Axis
    - Thrust: Forward-Backward
  - Along the Up-Down Axis
    - Lift: Up-Down
  - **DISTANCE**: Inches, Feet, Meters

- **Rotation Around an Axis (3DOF)**
  - Around the Side-to-Side Axis
    - Bend: Forward-Backward
  - Around the Front-Back Axis
    - Side Bend: Trail/Lead
  - Around the Up-Down Axis
    - Turn: Open-Closed
  - **ANGLE**: Degrees, Radians, Revs

How is this important to the golf swing? Every part of your body can be considered to move with 6DOF, for example, your pelvis (hips) at the address position will have a certain position and orientation and that will be a different position/orientation to the top of backswing and again different to impact and finish. So at the top of your backswing your hips will have turned, tipped sideways and tilted backwards. They may also have swayed sideways, thrust forward and lifted up compared to where you were at address. So to get all the motions we need to measure all six of these values; we need to measure in 6DOF.

By the way, your spine is not stiff during the golf swing; it is flexible and so your pelvis and thorax can move independently of each other; yes, in 6DOF. (Note; we use the term “thorax” to mean upper body or ribcage. Please see the explanation at the end of this article). You don’t only turn your spine during a swing; you bend and side-bend as well. In fact this is where you get a huge amount of your power from, but unfortunately if strength is not maintained it is also how back injuries occur. So, measuring these two prime movers (pelvis and thorax) in 6DOF during the swing is very important. Several systems out there today only measure angles (3DOF); they are missing half of the picture!
AMM 6DOF Systems
Advanced Motion Measurement, Inc., (AMM) has several systems that can measure 6DOF during the golf swing. They all include the TPI 3D biomechanics methodology. They range from the comprehensive full body AMM3D motion capture system using 12 electromagnetic sensors attached to your limbs, head and body; to the new three sensor Walkabout 6D Golf system that measures the club, pelvis and thorax.

Surprisingly with only three sensors the Walkabout system measures many important aspects of the swing in 6DOF. I'll discuss these systems subsequently but first I want to explain the Kinematic Sequence.

The Kinematic Sequence
All of the AMM systems measure the Kinematic Sequence of the body during the swing. This gives us a measure of the dynamic efficiency of the swing. It tells us how we are generating energy and whether we are doing it in the best possible way. The Kinematic Sequence is a measure of the turning speed of the pelvis and thorax, plus the swing speed of the arms and club shaft. It is a graph of these curves, (sometimes others may be added). An example is shown below.
There is a huge amount of information in just these four curves. We can tell the sequence of motion in your takeaway. We can tell the sequence of motion in your transition from backswing to downswing. The transition sequence is very important in power generation because of the way that muscles work. If a muscle is stretched before it contracts then it can contract stronger. This is called the stretch-shorten cycle of muscle. So if we see your pelvis transition before your upper body then we know that there is an extra stretch going on in your mid-section, helping those muscles to provide more power. The same extra stretch can occur at the shoulder joints and the wrist joints, and we can measure that too.
Surprisingly to some, during the downswing your body doesn’t accelerate all the way in to impact, only the club does. Actually each part of your body first accelerates in the downswing, and then decelerates just before impact. This happens naturally and is similar to “cracking a whip”. First the handle of the whip speeds up then it sharply slows down in order to transmit the energy to the tip of the whip so that it cracks. The analogy of the golf swing to this is not perfect but it is instructive. So in the golf swing all parts of your body and the club speed up during the early part of the downswing (as indicated by the up-slope of all four curves) but after a few fractions of a second the pelvis slows down and speed is transferred and increased across the core by the mid-section muscles. This allows the upper body to be “sling-shot” faster into the downswing. This sequence then repeats, with the upper body slowing down as the arms continue to speed up; energy is created and transmitted across the shoulder joint to speed up the arms. Next the arms slow down as the club is released into the ball with maximum possible speed. The characteristics of this downswing sequence are:

- first acceleration then deceleration,
- each segment’s speed peaks and decelerates after the previous one in a sequential manner,
- each segment’s speed peaks higher than the previous one, with speed being gained across each joint, caused by the timely action of the muscles across that joint.

In the picture below you can see all the kinematic sequence parameters that were measured and compared between novice and elite golfers in our research that was published in the World Scientific Congress of Golf proceedings (Cheetham, et. al., 2008), they include; accelerations, decelerations, timing
of peak velocities, values of peak velocities, speed gain from segment to segment, and calculated club head linear speed.

**Important Downswing Kinematic Sequence Values**

**Walkabout 6D Golf**
This system uses three 6DOF electromagnetic sensors to capture the position and orientation of the pelvis, thorax and club; 120 times per second during a swing. It uses the TPI 3D biomechanics and reporting software to produce the biomechanics report. It measures sway, thrust and lift of the pelvis and thorax; release angle of the wrist, X-Factor and X-Factor Stretch, to name a few. These values can be compared to our tour databases so the golfer and instructor will know what is in or out of range. The system also measures the Kinematic Sequence of the pelvis, thorax, arms and club shaft. These measurements allow the instructor to check most of the typical faults in the swing such as, address posture, C or S posture, sway on the backswing, slide on the downswing, hanging back, reverse spine angle, hip and shoulder over or under rotation, early extension in the downswing, flat shoulders, coming out of posture, over the top. In fact all of the “Big 12” faults that are taught at the TPI Seminars can be measured, plus many others as well.
An added benefit of the system, and some say its most important feature, is its biofeedback mode. Tones can be set on each of the motions and positions to indicate to the golfer when he/she is doing the motion correctly or incorrectly. Am I in the right position or the wrong position? The tone and the real-time numbers on the screen show and give the golfer the feel of what is right or wrong. This method when applied correctly speeds up learning.

The Walkabout system is quick and easy to set up yet very accurate in its measurements. It is tetherless allowing the golfer to “walkabout” without the hindrance of wires. During setup, offsets measured from the golfer are used to electronically move the sensors “inside the body” so the segment centers are measured instead of the segment’s surface.

**AMM Walkabout 6D System**

![AMM Walkabout 6D System](image)

**Self Contained**  **Quick to Set Up**

**AMM3D 12 Sensor Full-Body System**

This is AMM's flagship product and it captures the full body of the golfer plus the club in 6DOF at high speed (240 Hz). It is the most accurate of the systems but takes the longest to setup. The instructor must digitize body landmarks with a sensor pen. This is the most accurate method because it aligns the sensors to the body segments and scales them as well. Once digitizing is complete a full-body TPI 3D robot can be seen emulating the entire golfer’s motions in real-time. In addition to the kinematic sequence and pelvis and upper body 6DOF you also can get legs and arms motion; plus all the release angles of the wrist and forearm; flexion/extension, radial/ulnar deviation and pronation/supination. If you want to know everything about the swing’s biomechanics and have research quality data, this is the system to use.
AmmSensor (3DOF)
I have spent all this article so far talking about 6DOF, however 3DOF (angles) is still very useful, especially if it inexpensive and easy to use. The AmmSensor is an inertial wireless sensor that can measure three angles in real-time. It is hence very useful for biofeedback training applications. If put on the pelvis for example it can measure forward/backward bend, side bend and turn. Tones can be set on any of these parameters at any values. The golfer can practice feeling the correct position with audio validation tones. Two AmmSensors can be used together to give pelvis and upper body motion plus there relative motion as well (e.g. X-Factor).
A Note on Terminology:
Pelvis versus Hips and Thorax versus Shoulders
We use the term pelvis instead of hips and thorax instead of shoulders. Hips and shoulders can be confusing because it sounds like there are two of each of them, and there are. From my point of view the hip is a joint. It is where the thigh bone (femur) joins the pelvic bone (pelvis). The shoulder is also a joint (and a complex one at that). It is where the upper arm bone (humerus) joins the ribcage (thorax) and includes the shoulder blade (scapula). So I want to make it clear that we are not talking about the joints, we are talking about the body segments.

Thorax is a not well known term but it really means the ribcage area including the ribcage and the thoracic spine. Torso is also a well-known term but it actually includes both the pelvis and thorax.

So if we are talking about the specific body segment, we say pelvis or thorax. If we are talking about the joint then we say hip or shoulder.

References

© Phil Cheetham, June 2012
Michael Bentley

Michael is considered an industry expert in 3D motion capture technologies and analysis. His extensive research and expertise spans IMU, optical, and high-speed video technologies. Throughout his career, Michael has worked closely with leading specialists in human motion including Physicists, NASA Scientists, Biomechanists, Athletic Trainers, Physical Therapists, Sports Optometrist, Podiatrists, and Strength & Conditioning Coaches. Michael is a founder of Blast Motion, a company on the cutting edge of wireless motion capture.

http://blastmotion.com/products/

Golf Progress Commentary:
I wanted to include Michael Bentley as a primary contributor to this initial collection of writings about 3D golf because I view him as an innovator and a visionary. He developed the K-Vest which was the first commercially viable and still is the most popular 3D golf analysis product on the market. Whatever the “next big thing” ends up being in the 3D world, it will come as no surprise if Mr. Bentley is involved.

-Nick Chertock

1.) How did you get interested in 3D technology?

In the 1980s I was a hungry and determined touring professional traveling all across the globe. I was a solid player but could not figure out why my results were not improving on a more consistent basis. I logged long hours at the range, but did not reap expected benefits. Frustrated, I went to one of the top tour coaches in the world in search of definitive answers to my dilemma.

My new guru would help get my swing back in tune each time I saw him, but I always wondered why my swing fell off the mark whenever I didn’t see him for long periods of time. Because of this, I decided to eliminate the on again off again performance once and for all, and moved to be closer to my coach. Instead of getting better, I got worse. I even developed a new miss to the left and still didn’t fix my weak right misses. It wasn’t any fun to say the least.

At the end of the day, he didn’t have the answers I was seeking to my fundamental question. Per his suggestion, I sought the help of several notable sports psychologists, since he thought that the cause of my unchanging progress could be due to an unseen mental block. I was put through a battery of psychological screening tests and passed with flying colors—off the charts, in a very good way. So my problem definitely wasn’t mental— it was a swing issue, or was there something more to it?

I always intuitively knew that golf ‘tips’ weren’t long lasting. They were temporary patches, ‘fingers in the dike’ if you will. What I was after though, was golfing success, but no one was providing me with sufficient answers. I was seeking quantifiable proof as to why some golfers were successful, and why
others were not and no one in the golf world could give it to me. They would try, but there would be holes in each of their systems (if they even had one). None of the systems were based on scientific laws of physics or biomechanics, but often just hearsay, casual observations, or trial and error. Other systems had great logic, but no structure.

During my journey I have witnessed many golfers, both amateur and professional, searching for the secrets to golfing perfection. Up and down driving ranges one can observe many desperate golfers combining medications or prescriptions that have worked for a former tour star or golfing buddy, hoping for the same little taste of magic. Trial and error is valiant and there can be a time and place for it, but my lifetime is short, and time playing golf even shorter, so I searched onwards.

It was 1987. Confused, frustrated, discouraged, and about to go back to restoring classic automobiles, I came across an advertisement in the local newspaper. The ad highlighted a Los Angeles hospital that was doing a study on the biomechanics of golf, and was seeking test subjects. Since I was a touring professional, I thought I would be the perfect test model, and fortunately they did too. Maybe this biomechanics thing could provide me with some answers...

The study at the hospital opened many new doors and elicited a fury of fireworks in my brain. Maybe science, and biomechanics more specifically, could provide me with answers that the golf world was unable to. The sports scientists at the hospital were the first of many to guide me on a path, a path I wish I would've known about when I first began this addictive game.

Over the past 30 years I have formed relationships with the leaders in the fields of biomechanics, kinesiology, psychology, and athletic training in my quest of creating a non-subjective, systematic roadmap towards sustained excellence in the game of golf. This roadmap was to have definitive steps to follow that were all scientifically based.

I have since created such a roadmap based on all of my research, a progressive learning pyramid of drills and exercises, but always felt that having access to an objective measurement tool would help shorten learning curves and keep things objective. 3D technology has proved to be my greatest asset.

2.) Why is 3D superior to 2D?

3D technology allows an analyzer to learn things about an athlete’s motion that 2D video or a naked eye simply can’t see with any sense of accuracy. Most coaches, not knowing better or lacking access to spending money, still analyze swing technique with just video cameras, if they use any cameras at all. 2-dimensional analysis combined with 2-dimensional knowledge is incomplete—a dimension is missing. It’s like looking at a flat Monet painting, which would be fine if you are a curator at the Louvre, but our bodies, and therefore golf swings are 3-dimensional moving bodies, or spinning sculptures. It isn't appropriate to analyze the distorted painting when we have the ability to more accurately critique and measure the precision-formed sculpture.

When 30 curators look at a painting they may come up with 30 different subjective interpretations, which I suppose is synonymous to the Top 100 teachers analyzing the world's number 1 golfer with just 2D pictures or video; lots of opinions, but no definitive and objective answers. This is no man’s land, with too many nebulous threads.
We must strive to eliminate any subjectivity from golf instruction. Our students deserve solid and science-tested answers. Finally, in 2013, technology and knowledge gathered from many disciplines has evolved to a point where we can finally do that. Instead of supposing which methods are more effective than others, we can objectively measure all methods to support and refute any outlandish claims.

3.) How was 3D technology received when it was first brought into golf?

When 3D technology was first introduced to golf in the late 1980s, the process of collecting and analyzing data took not seconds, but days. It was thought of as more of a research project and not as a way to analyze the efficiency of a golfer. It was very difficult to communicate the information, and was often misunderstood because it came across as being too technical. Golfers and coaches alike did not understand the graphs, new data, or new terms.

Unfortunately, 25+ years has passed and not much has changed. There is only a very, very small group of individuals who are even aware of what 3D is, and what it can truly do in terms of injury prevention and distance/accuracy production. The beauty of 3D data is that it can be as simple or complex as you want it to be. The major question to ask when communicating data, 3D or otherwise, is how far do you want to go down the rabbit hole? One thing coaches have to be careful of is getting too excited and trying to tell their student everything they found in their 3D data. I use 3D to spot trends, and to find a golfer's weakest link so I can influence purposeful and permanent change. If we understand the forces that create the motion from the ground to the club we can then alter or enhance those forces to make the change that will allow the golfer to swing with a higher level of efficiency.

4.) Why isn't 3D more widespread in sport instruction?

3D has not been widely used in sport instruction because of three major issues: affordability, portability, and accessibility. Because of its expensive price tag, not a lot of people have been able to have a 3D experience. Even fewer have been able to have their swing measured on an actual golf course. Most have been turned off by GUI's (Guided User Interfaces) so complex that a PHD in Computer Science is needed to walk through the experience. Fortunately, technology is becoming smaller, less expensive, and easier to communicate. I can now say that by the end of 2013, consumers will have access to portable and affordable 3D sensor technology that can compete with a $250,000 optical system. The game is changing.

5.) Why are you a fan of 3d?

3D technology allows you to observe motion in a new way. With 3D technology, guesswork is completely eliminated and captures insights that human eyes simply can't see. Top coaches still think they can analyze a swing with their eye, and while it's possible to spot gross flaws without any technology, with technology, you gain access to the whole picture. Once you train your eye and are educated with 3D knowledge, you still can see bits and pieces, but you truly can't see whole story.

My favorite thing about 3D is that it explains the forces that create any athletic motion. Most golf coaches focus on what the hands, wrists, arms, and shoulders are doing, but fail to pay much attention to the feet, knees, or pelvis. They look at the net effects, but really need to look at the root causes. 3D tells the entire story.
Another feature I love about 3D is its ability to shorten learning loops via biofeedback. With biofeedback, golfers can instantly know that they are performing a move correctly (to the degree!), thus eliminating any guesswork, and ultimately eliminating the need for the constant vigilance of a coach’s subjective eye.

6.) Why are cameras not a stand-alone solution?

When using a camera, data can easily be skewed unless the camera is perpendicular to the axis of rotation. As an example, the rotation of the pelvis or thorax can change by 20 degrees just by changing camera perspective. For years we’ve been trying to emulate the best off a picture, a 2D swing plane, but that’s not the world we live in.

Instant 3D data, however, allows golfers and their coaches to instantly find weak links in a golfer’s swing, and discover things that go undetected or unquantified when using just video cameras or their naked eyes.

7.) What 3D Systems Have You Been Involved With?

I’ve been involved in many sport research groups, working with all types of athletes, but my three most current golf consumer solutions are K-VEST, ENSO, and BLAST.

K-VEST is a 3-dimensional 3-sensor inertial sensor system that I created in 2003 in an effort to bring wireless and relatively affordable 3D technology to golf. K-VEST stemmed from a dilemma I had working with some of the best players and teachers in the world; the drills I created and borrowed from biomechanics and sports science were too new and too different for most, so I needed an objective measurement system to instantly detect a golfer’s true swing inefficiencies, and track progress objectively as possible. Communicating this data was and still can be a challenge, but K-VEST helped golfers to really begin to understand their true swing efficiency.

After each swing, data gets sent instantly and wirelessly to a laptop that generates an instant report card based on a golfer’s swing. In addition to the report card are several force/time graphs. Perhaps the most important graph is the kinetic chain graph, a swing efficiency measurement graph.

I loved creating K-VEST, it was state of the art at the time it was created (and continues to improve every year), but felt limited by technology constraints, which caused me to move on and pursue other solutions.

After K-VEST, I had the opportunity of partnering with 2 powerhouses, Fujikura (a leading golf shaft company), and Vicon (a leading motion-capture company) and created ENSO. ENSO is a 3D shaft analysis system that uses highly expensive Vicon infrared cameras (the same ones they use to make 3D movies like Avatar, and EA Sports video games) to detect shaft movement in a 3D world. It was really expensive technology ($100,000), but was perfect for shaft fitting and research. I wanted to create ENSO because I viewed knowledge about the shaft as a gaping void in my goal to crack the code of golf.

Advances in different types of technology have allowed teachers and club fitters to optimize ballflight with launch monitors, and body motion with 3D motion capture technologies; however, aside from simple physics models (ie double pendulum), the shaft and clubhead have never been measured with much precision and accuracy aside from small research labs.
ENSO stemmed from wanting to know shaft behavior throughout a golfer’s swing pre-impact. Was the shaft a golfer was using adding or taking away energy from the energy the golfer was able to produce with his or her body? During my time with ENSO I learned many things about the performance of a shaft throughout the golf swing, but saw the consumer need for developing a ‘smart’ golf club, and thus created Blast.

With 25 years experience in the 3D motion capture world, I intuitively knew that inertial sensors would quickly become the smallest, most accurate, and inexpensive solution to measure motion in 3D. Since creating K-VEST in 2003, the cost and size of inertial sensors has decreased astronomically: what used to cost $1000 and be the weight of a smart phone now costs $150 and is the size and weight of a quarter. My vision of creating an accurate, portable, and affordable 3D sensor is now becoming a reality.

The Blast sensor is the combination of K-VEST, ENSO, and even a launch monitor, and is placed securely in the butt of a golf club. Blast is the most portable, accurate, and affordable way of measuring a golf swing ever created. Blast captures data at 500+ frames per second, more than enough to observe every move in the golf swing.

After each swing, BLAST instantly sends information wirelessly from the sensor in the club to a golfer’s smartphone or tablet, completely eliminating the need of a computer. Data also gets sent instantly to the cloud so that any golfer in the world can observe a golfer train, or even compete against his friends, or favorite pro in real-time.

8.) Other sports have used biomechanics and 3D to their advantage, golf should too...

Definitely. Other sports have embraced sport science, and golfers are just beginning to. We need to remind ourselves that we’re all athletes and to optimize our bodies and swings, we need to keep teaching and learning objectively. We need to use science to play better golf. To keep moving this game forward, we need to bring in simple things learned from sport science to this game we all love.

Sports like track and field continue to succeed in pushing the performance envelope, yet golfers by and large have struggled and performed at the same level for many years. In the 100 meter sprint it is easy to measure the performance of an athlete by his or her time recorded on the stopwatch. However, in the game of golf, there are more variables to measure than just the final score. In the sprinter’s world we can see how each athlete trains his body and mind to keep climbing to the next level. Golf needs to be the same way.

The information 3D technology provides may overwhelm you for a second because it is new and different, but if you apply it to your own game, you will instantly start to play golf safely, purposefully, and powerfully.

9.) Why do golfers need to embrace 3D ASAP?

The old traditional ways of playing golf are dying. Courses are getting longer, equipment is getting better, and most golfers still know nothing about how the body influences the golf swing. The answers are at our fingertips, and we cannot be held back any longer by fallacies. Hitting and hoping, needs to die. Golfers need to transition towards hitting to knowing, making the leap from band-aid tips to long-term solutions.
With the progress made in technologies, we need to eliminate feels and rely on objective metrics. We must understand the forces that create the motion so we can alter the necessary forces required to create a desired outcome. We will move from swing styles to swing efficiency. The bottom line is this: If you don’t measure it, kinetics and kinematics, you can’t improve it.

Embracing 3D is a shift. Other sports have used science, but science really hasn’t been applied to the entire game of golf. The same drills, same sayings, and same old thoughts have been passed on for decades. But tradition holds us back. It’s time to evolve.

The good news is that guessing is over. We need to make the transition from 2D to 3D, and apply 3D knowledge in a 3D world. We walk, move, and see movies in 3D, it’s the easiest way for us to process information and easiest way to learn. Golf needs to evolve with the rest of the world.

10. Does the Idealized swing exist?

Yes and no. Keep in mind that physical, mental, emotional, attentional, tactical, or mechanical limitations can be detrimental to total optimization, and we all have some degree of system errors. That being said, it would be an ambitious and valiant goal to try to correct all physical, mental, and technical faults or restrictions. If you want to be the best golfer in the history of the game, this is the least that you should be doing.

As it stands now does the idealized swing exist? That is a very logical question, but is difficult to narrow down to a single player. Parts of certain golfers are perfect, but not all parts are perfect in one singular golfer

The elite golfers on the PGA tour are very successful despite biomechanical short-comings and thus have immense room to improve. The problem is that the more you add compensations for biomechanical breakdowns, the more critical your timing becomes. When timing is off, shot performance suffers.

But somebody has to win; it’s a competition. You have to beat someone else who also isn’t optimized. But imagine if you were more optimized than they were... This is why science needs to be our friend, and 3D is an invaluable tool to have in your arsenal.

Read Golf Digest’s article from 2007 naming Michael Bentley as one of three innovators “leading the charge” toward modern instruction with his development of the K-Vest:

PENN STATE Golf Biomechanics Laboratory

Mike Duffey, Ph. D

Mike Duffey earned his M.S. in Health & Exercise Science from Wake Forest University in 1996 and his Ph.D. in Kinesiology (with an emphasis in Biomechanics) from Penn State University in 2009. Mike works closely with Eric Handley to conduct golf specific research at Penn State’s Golf Teaching and Research Center.

http://www.hhdev.psu.edu/rptm/gtrc/people

Eric Handley

Eric Handley is a PGA professional with his Masters in Sports Management from North Carolina State University. He is the Director of the Penn State University Golf Teaching and Research Center and leads all of the golf instruction and research programs for their PGA Golf Management Program.

http://www.hhdev.psu.edu/rptm/gtrc/people

What system is used at the lab and what is the purpose of the golf lab?

The Penn State Golf Teaching & Research Center (GTRC) is a unique teaching and research venture designed to lead university instructional and scholarly initiatives related to the golf industry. The GTRC works directly with the PGA Golf Management program at Penn State University to help their students be better players and teachers of the game upon graduation. In addition to individual and group instruction, the Penn State GTRC is able to collaborate on innovative research projects and product testing by combining university resources within our PGA Golf Management program, Department of Kinesiology, and the Penn State Golf Courses and Athletic Department.

Our teaching comes in two formats: we do some traditional individual sessions where we will take a student and do a one-on-one session looking at the strengths and weaknesses of his or her swing. We also do classroom-based teaching, where we discuss general tendencies and variations across swings. To support this teaching, we have and continue to collect a large volume of swings and maintain a database. By maintaining our own database we are able to look at differences in swings based on characteristics like swing style, gender, or handicap.

In regards to 3D motion capture, we have two systems at the GTRC that we have utilized. We initially started with the Advanced Motion Measurement/ TP13D system. And, from time to time we still utilize this system, more as a teaching tool with our PGA Golf Management students. It serves its role well. We continue to use it on occasion, especially if we are going to go outdoors.
However, more recently we have been conducting research related to the biomechanics of the full swing and putting stroke as they relate to the golfer’s playing and athletic abilities. When it comes to research, we have been utilizing a nine-camera Qualisys system at a capture rate of about 250 frames per second (fps). We have positioned these cameras around the player in positions that allow us to capture the entire swing, including the club, for right and left-handed players.

We analyze our data using a golf-specific package in the analysis software program Visual 3D which was developed in a collaborative effort between ourselves, Qualisys and Visual 3D. The Qualisys/Visual 3D system has several benefits that suit our needs: It allows us to collect data on golfers more quickly than most other systems. It allows us to analyze either a single swing or multiple swings immediately. We are able to look at all of the data for the whole body or we can quickly look at a single rotation or velocity.

How 3D benefits a teacher

As a teacher, 3D technologies are tools that can provide us with greater amount of in-depth information about a student’s swing. The first benefit of a 3D system is usually the capture rate. At 250 fps, we are able to capture data at about every 4 milliseconds. This rate is typically much faster than that of many “off the shelf” video cameras.

Another benefit to these systems is being able to view a student’s swing from any angle or zoom level imaginable. It’s like having an infinite number of cameras at any given location. We are even able to view a player’s swing from below what would be the floor, if we choose.

Maybe even more powerful than the visual abilities of a 3D system, are it’s capabilities to capture data and allow us to analyze in great detail. As a researcher, being able to evaluate the golf swing by comparing numbers at a given time for a given segment (ex. amount of pelvis rotation at impact) allows us to conduct more detailed analysis.

From these research studies, we hope to learn more about how to improve player performance, and also help our PGA Golf Management students graduate as more knowledgeable instructors.

How 3D benefits students

Some of our students enjoy the visual and auditory feedback they can receive from 3D Motion Capture (as mentioned previously with multiple camera angles and numerical data). However, it seems that our students improve most when the 3D data is interpreted by one of us in the lab along with the student’s PGA Golf Instructor. We are able to analyze parts of the swing that would not otherwise be possible, even with high-speed 2D cameras.

It is very useful to be able to provide measurable data and feedback to a student regarding various parameters. An example might be the amount of sway of the pelvis at the top of the backswing. We can show and tell the student how much they have improved or how close they are to making the change (ie. going from 3 inches of sway at the top of backswing to 1.5 inches). Hearing, feeling, and seeing the desired adjustments are extremely valuable for the students.
In addition, the end result of a particular ball flight typically comes down to one of three variables, or pieces of “equipment,” 1) the ball, 2) the club, or 3) the body. By combining ball flight monitors, with club delivery and impact information, and 3D biomechanics of the golf swing, we have a large amount of information that we can gather and analyze to help us understand how each variable (ball, club, and body) contributes to the resulting ball flight.

What are some of the misconceptions about learning indoors using technology?

One concern about learning indoors while utilizing different technologies is the question of accuracy. Many golfers believe that the equipment used to measure the golf swing indoors is less accurate than if that equipment were placed outdoors. In some settings and with some equipment, this can certainly be the case. However, with the 3D Motion Capture systems often times we are able to eliminate some of the excess variables. An example would be with our Qualisys 3D system, camera positions and calibrations can be held with extreme precession while indoors, and excess light from the sun in an outdoor setting is also eliminated. Eliminating both of these variables can help improve the quality of our data.

What should people know who have never used 3D before?

For PGA Professionals, it’s relatively easy for most of us to jump right into 2D video and ball flight analysis. However, if an instructor is interested in 3D technologies, I would want him/her to be aware of the vast amount of information that is available from these systems. It is easy to become overwhelmed very quickly and lose sight of the bigger picture. Every PGA Professional can benefit from some of the great resources that are available for continuing education from resources like the Journal of Applied Golf Research (JAGR), the World Scientific Congress of Golf, the Titleist Performance Institute (TPI), peer-reviewed research articles, the Golf Professional and Golf Biomechanists Facebook groups, and more.

For a student, I think it’s important to understand that 3D technologies are yet another tool that is becoming more widely available for golf instructors to utilize. While it is not the “answer” to every student’s problems, it can help instructors more accurately identify abilities and limitations that may be contributing to the swing we see in 2D and the resulting ball flight.

What do you see as the future of learning using this kind of technology?

The future of learning and using advanced technologies is extremely exciting. I can envision a day within the next few years where we are able to collect data from a golfer’s swing and ball flight during an actual round of golf. These technologies are becoming more and more mobile, less expensive, and networked directly back to the golfer’s PGA Professional. Imagine finishing a round of golf, and by the time you walk back into the clubhouse, your instructor has already received ball flight details from your round, along with 3D data, on-course statistics, 2D visuals, golf fitness abilities, and more.
A tool that until recently has only been available to golf club manufacturers, research institutions, and PGA tour pros has become increasingly available to you, me, and our students out on our practice ranges and golf courses. The future of 3D motion analysis as applied to the golf swing is here now. Capabilities that were once only available in systems costing upwards of $20,000 are now part of products and services costing a fraction of that. Barriers to entry into the most advanced methods of evaluating our golf swings are coming down with each new advance in hardware and software technology. Now it’s up to us to learn how to evaluate what’s best for us in our businesses, and how to best use these exciting services and technologies to help our clients improve their golf games.

Just as video rapidly became a tool in every golf professional’s teaching kit as technology became more portable and less expensive, 3D analysis hardware and software is poised to become the must have golf swing analysis tool of the 21st century. The application of 2D video analysis helped inform a revolution in golf instruction. The data that you can collect, though, is far more revealing than what’s available from 2D systems. Within seconds, I have available a summary of my student’s swing “efficiency” with segmental sequence and rotational speeds, a precisely measured data sheet of my students rotation, front and side bend measurements at address, top of backswing, and impact with comparisons to PGA or LPGA Tour averages, a graphical representation of my student’s kinematic sequence, and an animation of my client’s pelvis and torso with the 3 degree of freedom measurements that I can examine from six different perspectives. I also have that data available in TPI 3D format, with four different performance graphs and six different report printing options. Yes, there’s a video input too, and KVest can connect to force plate and ball flight monitors as well. Subtleties in golf swing mechanics invisible to the naked eye are easily apprehended by the teacher, and for the first time became available for the student to see.

It’s almost hard to imagine the far reaching influence that the availability of 3D analysis can have on our understanding of the golf swing. In addition to being able to “see” the body’s position in all phases of the swing, 3D tools can accurately quantify that movement. With 3D tools, the golf professional can now measure postural relationships and segmental speeds at any point in the swing, and can quickly assess how any suggested changes might affect those parameters. Some systems even offer biofeedback capability that enables the user to precisely “step in” to the positions and movements that the instructor recommends.
One of the pioneers in the application of the principles of biomechanics to analysis of the golf swing offers one of the most affordable entries into the world of 3D motion analysis. Chris Welch, founder of Zenolink, is a biomedical engineer, and has been involved in the analysis of the golf swing, and the development of 3D measurement systems since 1991. Zenolink offers a service, based on a video platform that can offer you and your clients a very affordable way to not only capture 3D data on their swings, but gets you access to Chris’ 20 plus years of experience and expertise. For the small investment of purchase of a calibration “cube” from Zenolink, and capital investment required for the purchase of 2 video cameras and a laptop, you can be in the 3D business. Chris offers his services on a “pay as you play” basis, allowing you to videotape your students, uploading the video to Chris at his office near Binghamton, NY. Chris digitizes your images, provides a detailed analysis via a web based platform, and prescribes a Progressive Skills Training program to help your client adapt to the motor pattern changes that you prescribe to improve their biomechanical efficiency.

For those that like to have 3D analysis capability in their hands, KVest provides another cost effective solution. KVest was founded by PGA Professional Michael Bentley in 2005. It consists of a system of 3 small inertial motion sensors that are attached at the golfer’s upper body, pelvis, and the back of the lead hand. The sensors transmit a radio frequency signal that is picked up by a receiver that is attached via USB cable to a laptop. (There's now a Bluetooth option available as well) Each sensor can measure the forward bend, side bend, and rotation of the segments to which they are attached, and can also measure each segments speed. The data collected is displayed to the student as a computer generated avatar of upper body and pelvis that can be displayed from six different perspectives and all of the bend, tilt and rotation measurements can be displayed on the monitor. Data can be displayed in graph form, and there is a summary of swing “efficiency” and of the positions of the pelvis and upper body at address, top of backswing, and impact as compared to PGA or LPGA Tour norms. The now generally recognizable kinematic sequence graphs can be generated for every swing, and graphical analysis is available for each segment individually. All of the data can be compared to data collected by the Titleist Performance Institute, and reports can be printed comparing the student’s performance to PGA, LPGA, or Champion's Tour averages.

One of the advantages of the KVest platform is that the student can utilize its biofeedback capabilities. For any combination of thorax and pelvis positions at address, transition, or impact, values can be entered for the student to match. When the golfer successfully attains the recommended position, the avatar on the monitor turns from red to green and a pleasant audio tone sounds. This provides a very precise way for the student to kinesthetically experience the body positions that the teacher recommends in the golf swing.

In the interests of full disclosure, I’ve been a KVest customer for 5 years. I’ve found the system to be a tool that makes it possible to effect and precisely quantify swing changes in as little as one session. It’s not only effective, it’s entertaining as well. KVest’s biofeedback capabilities provide an interface that’s as engaging as a video game.
The system can be set up in about five minutes, and calibration and swing capture is no more difficult than working with your video system. With all of the 3D data available, a teacher can rapidly pinpoint mechanical breakdowns, and KVest’s biofeedback capabilities are powerful. Just today, I had a student who was concerned about his inconsistent golf swing. I was able to quickly show him that the variation in his results could be closely correlated to how well he sequenced his swing. His well struck shots showed a relatively efficient kinematic sequence, his poor ones were very noticeably out of sequence. I could demonstrate to him that his poor sequence resulted in a very weak impact position, then, with biofeedback allow him to precisely experience how a proper impact position would feel. From there we worked on a simple drill that reinforced that position, and we could measure his performance while we did it. When we went back to the full swing, we could look and see exactly how much his swing had changed. His sequence was much improved, and impact position had gotten much closer to what we were looking for. I had a client who was excited and energized about prospects for improvement that could be accurately measured, and who was looking forward to how productive his practice (and our next session) might be.

New technologies and new applications are constantly being developed, and some exciting improvements to existing systems are on the near horizon. As they become more affordable, the remaining challenge to golf professionals is to learn to use these tools effectively to help our students get better faster.
Tyler Ferrell

Tyler has almost a decade of experience using 3D motion analysis as part of his golf training programs. He is one of the few in the world to have earned every credential TPI has ever come up with. After starting his career working with Dr. Greg Rose at ClubGolf in Maryland, he has performed 3D motion analysis in Asia as well as around the US. He currently resides, and trains golfers, in Denver.

http://golffitnessguys.com/about/tyler/

I have been doing 3D motion analysis of the golf swing since 2004 and have used the AMM system almost exclusively. For six years I worked at Clubgolf Performance Center and did about one hundred diagnostics each year. I now have my own 8 sensor system and do diagnostics in Denver Colorado.

One of the big advantages of the AMM system with TPI-3D software is the advancement in the accuracy of the data due to the process of manual digitization. Prior to this upgraded software we would snap align the player prior to the data capture. The snap alignment disregarded postural individuality making the assessment of posture curves more difficult and less accurate, but the biggest issue was with analyzing the pelvis and the thorax in the linear movements.

Because the sensor was on the outside of the body there was lateral movement measured anytime there was a rotational movement. I would often see a pattern that looked like a sway, but it was just a player rotating their pelvis a lot. In addition, I often did not see players having a sway, when they clearly did on video. The same issue occurred with the thrust pattern. This difference in the video and the 3D made it difficult to have communication with golf pros because they would not always understand the importance of the kinematic sequence, and our data would not align on the lateral movements.

The updated software and digitization process made the linear movements much more accurate and easy to read. Because of the more accurate data, we were able to do biofeedback on sways and early extensions that previously didn't work. The newest version is as accurate as I need to do any of my evaluations and the added ability of real time biofeedback training is priceless in terms of speeding up the learning process. I have an 8 sensor system, so I am able to do biofeedback training on the arms, hands, thorax, and pelvis and have had great success getting students to change their kinematic sequence much faster than in the non-digitized version.

All of the 3D systems are capable of measuring a kinematic sequence, but the reason that I use the AMM system is the accuracy of the data due to the digitization process and the ability to do biofeedback training on the linear movements of the body and the movements of the elbows and wrists. The arms and hands move so much that even with the advent of high speed video, it is sometimes hard to see exactly the timing of key movements of the elbows and wrists. If you are just looking at the body and not looking at the arms, you could miss a key reason why the body will be out of position. If you do not train the arms and hands, then the body will struggle with making a change.
Jon Sinclair

Jon is the owner of Sinclair’s Golf Training Center in Euless, TX. He is a PGA class A member, a Master GolfPsych Instructor, a TPI and AMM-Certified Bio-mechanist Instructor, a Trackman Certified Professional and a Certified Sam PuttLab Instructor. Jon’s teaching facility represents the future of golf instruction, giving the student access to all the latest technology as well as instructors educated in how to leverage these tools.

http://www.sinclairgolf.com/

The importance of 3D and how it can help the golf instructor

The importance of 3D has several dimensions in the world of golf today. We can now see the unseen. It is used for physical fitness, physical therapy, motor skill learning, proving or disproving methodologies, research, club fitting, and instructional education. Instructors, physical therapists and trainers are more effective with the data provided in developing programs for their clients. Being able to actually see the motion patterns of the body in detail and how different segments relate to each other speeds up the process of delivering the proper information to the client. This in turn speeds up the learning curve of the client and minimizes frustration and potential injuries that occur when the body is not moving correctly or being told to try and move in a way that it is just not capable of moving. In my opinion the cost and ease of use is the only thing keeping it from being in every teaching facility in the world.

The 3D device that I use is the AMM 3D with the TPI reports. I see a lot of instructors overwhelmed when they first see the amount of data and how it is presented. The graphs, terminology, and numbers are quite a bit to take in at first and often it turns them off and they do not use it anymore. I would however encourage all instructors to at least try to dig in and start to learn how to read this information. It is not necessary to become an expert all at once. Just take a few ideas at a time and then you will find it less and less intimidating. If after trying to look at it, you still prefer not to use it seek out a qualified individual that is trained and let them provide you with a simplified summary of the areas you need to see. This has worked very well for me over the years. I have worked with many instructors, trainers and therapists and together we have helped thousands of players get better quicker.

I hope this short article will help you make the decision to start using 3D. I know the use of 3D has made me a better instructor. There are many thoughts and ideas that I have taught in the past that I now know to be ineffective or just plain wrong. So please give it a try or at least ask someone to help that is in your area. The ultimate goal is to make the client better and in this day and time there is so much technology out there that can help us do a better job.

Jon Sinclair
Sinclair’s Golf Training Center
Don Parsons

Don is both an accomplished player and respected teacher in the Santa Barbara, CA area. Don has been a PGA member since 1993, is a TPI Level 3 Golf Fitness Instructor and a Level 2 Golf Biomechanist. Don owns a teaching facility, “The Studio” at Twin Lakes, a state of the art teaching and practice facility in Goleta, CA. Don’s teaching philosophy is focused on swing efficiency. He won the California State Amateur Championship in 1988 at Pebble Beach.

http://www.thestudioattwinlakes.com/

When I gave my first golf lesson in 1990, I used an 8mm camera and drew lines on a 13” television with dry erase markers. As a competitive player I operated a club repair shop because I found that custom fitting shafts and shaping my woods helped with performance. In 1998, I met Kevin Brown and he taught me the importance of functional movement in athletic endeavors. We were partners for over 12 years and the tag line for Performance Golf of Santa Barbara was “Where swing mechanics and Biomechanics Come Together.” Our mission was for him to make a body as functional as possible and for me to create a swing that would work with what the player had to offer. We focused on enhancing performance by reducing pain and reducing the moving parts of the swing. We referred to this process as making our players “efficient”. But, what frustrated us both was that the results we got were anecdotal. There was no way to quantify what we did.

In 2004, I met Greg Rose at the Titleist Partner’s Conference and my definition of swing efficiency changed forever. Greg exposed me to 3d modeling and the kinematic sequence. I bought one of the first KVests of the line and have been using it regularly since. With the KVest, I am able to quantify “efficiency” and use the improvements in the kinematic sequence to ensure that the changes I make to a player’s swing are more than just stylistically better.

I use 3d in several ways during a typical program. I assess and alter swing efficiency by using the kinematic sequence and observing rotational movement patterns of the pelvis, torso, and hands as they relate to one another. I assess pelvic and torso positioning during the swing to determine if a player is in a mechanically advantaged position to develop speed, and deliver the club to the ball in a way that will create optimal ball flight. I use training features to help players understand the movements I want to encourage in the swing. Finally, I use the positional data to track changes with my players and keep a database of “great” data when my players are playing particularly well. By having this information if a player loses their way, we can get them back to their previous form.

The kinematic sequence has been a valuable tool for me in my teaching and coaching. I use the kinematic sequence graph as a measurement of the work I am doing with a player. Each swing change should produce a improvement to the sequence, or if the change is geared toward ball flight it should not denigrate the sequence. Many times when coaching, a change we make can have unintended consequences. By being able to measure the kinematic sequence I have been able to reduce unintended consequences by altering course when a change has a negative effect.
Derek Hooper

Derek Hooper is the Director of Instruction at the Troon Golf Academy Lake of Isles, Connecticut, and has been delivering coaching programs at the facility since its opening in 2005. Prior to his arrival at Lake of Isles, Derek was the Director of Instruction at the David Duval Golf Academy in Japan.

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I have been using the Golf Biodynamics 3D swing analysis system with my students for the past 4 years. As a result of using the system and the training I have received from Dr Rob Neal, I have learned so much more about how the body works during the golf swing than ever would have been possible through using video alone. It is also a wonderful diagnostic tool that allows me to measure body rotational speeds, body movements and body segment sequencing. All of which I can not measure using video.

The feedback I have had from students using the system has been extremely positive. They learn so much more about how certain body motions effect the way in which they move the club and thus generate power and distance with their shots. However the biggest benefit is derived from the biofeedback which the GBD system allows. I am able to select a particular body segment and set parameters within which I would like the student to stay during a designated part of the golf swing. If the student moves outside these parameters, an auditory tone is emitted by the system and the student knows to adjust accordingly. This form of immediate feedback during the golf swing allows students to understand what is required and encourages them to make the necessary adjustments to achieve the desired result. This type of instruction also allows students to make changes to their motion much more quickly than they would with traditional forms of feedback.

We are very fortunate at the Troon Golf Academy Lake of Isles to have four teaching studios that open out onto the driving range. This allows us to teach year round even though play on the golf course is seasonal. When the weather gets too cold we will close the studio doors and hit balls into a net. This is the perfect time to work on changes to a players swing mechanics. Too often a player will let the results of the ball flight over-ride their focus on a mechanical swing change and thus the change will be more difficult if not impossible to achieve. By working indoors the student becomes focused exclusively on the 3D biofeedback and this allows a much more efficient change in swing technique. Once the student becomes accustomed to the swing change and is able to stay within the set parameters hitting a ball into a net, only then would I take them to the next level by opening the studio doors to the range and asking them to repeat the new swing motion while hitting balls to targets.

3D swing technology is still fairly new in the golf industry and as yet is not a part of every instructors tool kit. Thus it can take a little research on the part of the student to find an instructor who utilizes this technology. Players can be hesitant to use such technology to improve their golf game, often fearing that they are not a good enough player to warrant its use or are concerned that the amount of
information such a system presents will only confuse them. In the hands of a quality Instructor the 3D technology can definitely help any player to better understand what is really happening in their golf swing and thus what changes need to be made to help them achieve their goals. Any player who is serious about playing better would benefit greatly from a 3D swing analysis with a trained Instructor. I have always liked the phrase that "you can't manage what you can't measure". In working with students the 3D system allows me to measure everything, but to only highlight the relevant areas to the student, and then together we can track the changes over time through the data the system provides.

Technology is changing and improving daily, and the upgrades being made to 3D swing analysis are no different. As the prices of these systems comes down, they will become more common and will become part of very Instructors swing analysis tool kit, as common as video swing analysis is today. With that will come more accurate information for both the Instructor and student, leading to more accurate diagnosis of swing faults. This coupled with the biofeedback 3D systems allow, will shorten the amount of time it takes for a student to learn swing changes.

The future of 3D swing analysis technology is very bright, and the more golfers that get to experience it the better the golf they will play.

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Resource Page

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David Watt  
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Terry Rowles  
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Publisher’s Notes

The purpose of this publication is to provide an introduction to some of the 3D systems that are available, and to allow the innovators in the field to express why they believe this technology is useful for the golf improvement process.

In the end, the golfer of course will not play better simply by having more data, there will need to be an application of the knowledge gained. However, it is always going to be easier for the player to progress more quickly armed with the right information about where their motion is failing them.