VICONPEAK

THE STANDARD

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SOMETHING NEW IN SPORTS SCIENCE

– alternating between theory and practice

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Figure 1 Sport Performance and Clinic Laboratory (SPEC). SPEC was opened in October 2003 in affiliation with The Institute of Health and Sport Sciences, University of Tsukuba, Japan.

Introduction

A 75-minute bus ride from Tokyo International Airport, Narita, brings you to the University of Tsukuba located in the center of Tsukuba City with stimulating natural and cultural surroundings. The University of Tsukuba (UT) consists of seven college clusters and schools, and 27 research institutes. The School and Institute of Health and Sport Sciences (IHSS) has approximately 1,000 undergraduate students, 360 graduate students and 130 faculty and staff. Its excellent education and research occupy a leading position in the field of sport science in Japan. To attest to this position and contribution to the field of sport science, the Sport Performance and Clinic Laboratory (SPEC, Figure 1) opened in October 2003 in affiliation with IHSS.

SPEC has three floors. The second floor provides athletic rehabilitation to athletes recovering from injuries and those seeking performance improvement. The third floor assists athletes with mental conditioning as they cope with the extraordinary mental stress involved in athletics. Nutrition analysis and advice is also provided. The first floor houses the Laboratory for Sport Biomechanics (LASBIM), where the biomechanics of athletic performance and motion is investigated, and coaches are educated in biomechanics and coaching techniques. Figure 2 displays the central area, which is wide and high enough to investigate the biomechanics of most sport techniques using a Vicon system employing nine cameras, three high-speed VTR cameras, three Kistler force platforms, a portable EMG system with eight channels, and SIMM (MusculoGraphics Co.) software. The editing of video images recorded in various aspects of training, games, and competitions is performed here to create image documents for coaching and teaching sports.

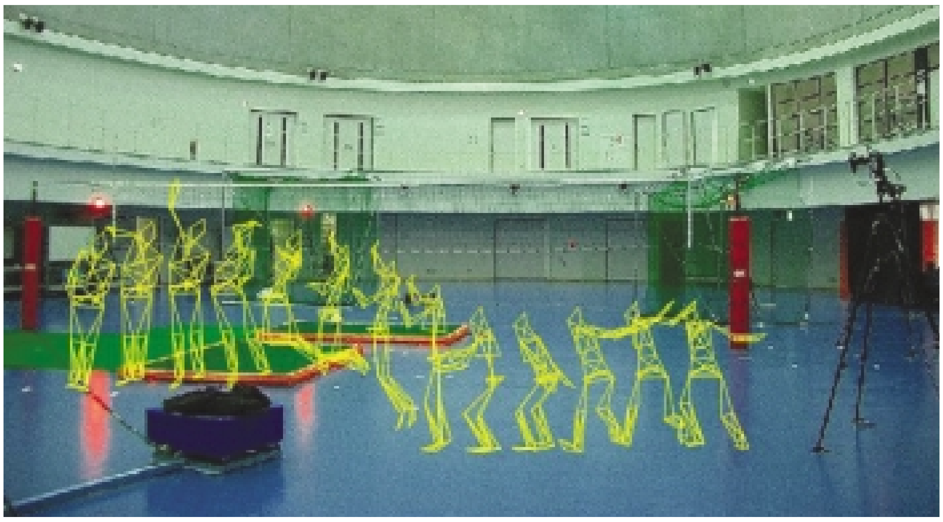

Figure 2 The central area on the first floor of SPEC. The first floor houses the Laboratory for Sport Biomechanics (LASBIM), where the biomechanics of athletic performance and motion is investigated, and coaches are educated in biomechanics and coaching techniques.

LASBIM concept

LASBIM's primary purpose is to educate students and graduate students majoring in sport biomechanics, and to perform research in sport biomechanics with an emphasis on motion analysis, computer simulation of sports, and sport engineering. The staff consists of Dr. Ae from sport science, Dr. Fujii and Dr. Koike from engineering, 18 MS and PhD graduate students, and 25 undergraduate students. Many students are top-ranked in both academic and athletic performance. LASBIM's major priorities are to investigate the biomechanics of human movement and techniques in various sports, physical education for the improvement in performance and the prevention of injuries, and finally to contribute to theory and practice in sports.

Figure 3 (overleaf) illustrates a system to reach these goals as a loop for optimization of sport techniques. We believe that the acquisition of proper sport and movement techniques is mandatory for good performance and safety, as well as for lifetime sports enjoyment. In optimizing sport techniques, coaches and teachers prepare by collecting appropriate information on techniques and training methods. They observe the movement of performers and athletes, evaluate and diagnose them, design appropriate training methods and workouts, and suggest techniques to improve performance. In observing and evaluating sport techniques, coaches and teachers implicitly use a model for good techniques. Since no evidence-based model of good techniques exists, most coaches and teachers employ the movements of athletes and champions in their own imaginary

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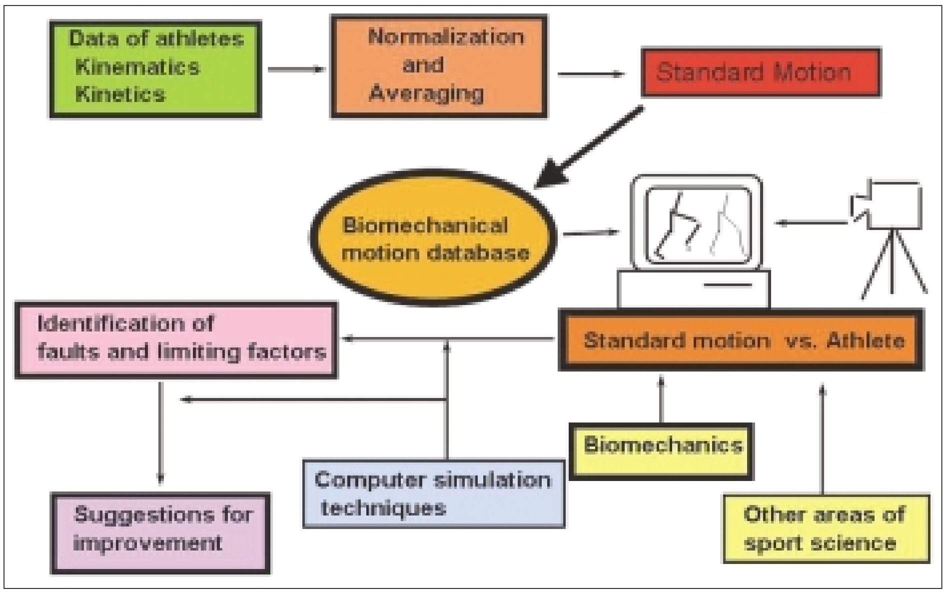


Figure 3 Optimization of sports techniques and "Standard Motion".

models. In a health examination, a medical doctor examines the body by monitoring blood pressure, ECG and other vital signs, and evaluates and diagnoses the patient's health, comparing the patient data against medical standards. We can apply a similar flow to evaluate and diagnose an athlete's technique if a standard of sport techniques exists. We have been trying to establish "Standard Motion" for good techniques through analysis, normalization, and the averaging of motions of skilled athletes. Figure 3 incorporates this "Standard Motion" into the optimization loop. We also collect biomechanical data from athletes who participate in official competitions and games, and feed this data back to athletes and coaches. We always try to shuttle back and forth between theory in the laboratory and practice on the sport fields. These steady activities and research bring us closer to understanding the mechanism of human movements and their enrichment of sport life.

Ongoing research at LASBIM

Ongoing activities at the LASBIM include the following:

1) Baseball project: Biomechanical study on baseball pitching and batting. Figure 4 depicts how baseball pitching data is collected, and indicates the changes in pitching motion from the first inning to the seventh inning, where the ball velocity gradually decreased. Daisaku Hirayama, a PhD student, asks varsity club pitchers to throw over 100 pitches and investigates the effects of fatigue on the pitching motion and the load on various joints. The upper torso and pelvis rotations in the seventh inning at the instant of the Stride Foot Contact (SFC) were significantly greater than those of the first inning. This indicates that the upper torso and pelvis were open at SFC. The forward rotation of the trunk and the backward tilt of the shank at the release of the ball (REL) in the seventh inning were significantly greater than those of the first inning. It may be easier to tilt the trunk forward if the shank tilts backward. This implies that the increased forward tilt of the trunk and lower position of the elbow at REL are compensatory changes to maintain ball velocity under the fatigued condition.

2) Good athletes projects: Good basketball, judo, soccer, tennis and volleyball athletes participated in a data collection session to establish "Standard Motion." Figure 5 presents stick pictures from the Judo project, and Figure 6 displays women's volleyball players setting toss and spiking the ball in which we investigated spike motion and a combination of the two players. For track and field, we investigated most of the events, including race walking, sprint, middle- and long-distance running, high jump, long jump, hammer throwing, and pole vaulting, in which we estimated pole reaction force. Although we were not able to use the Vicon system for track and field, we tried to collect 3D data of sprint and hurdling on the outdoor track with the appropriately set Vicon system, and successfully analyzed these techniques in 2005. We plan to apply this technique to other events, extending the Vicon's usability.

3) Athletes' gait project: Gait is one of the most complex human movements. Injuries incurred by inappropriate sport technique and athletic training may alter the gait pattern and joint motion, especially in the lower limb joints of the athletes. Investigating gait asymmetry of injured athletes enables us to collect information on functional compensatory mechanisms to alter leg-joint constraints caused by injuries, and to obtain clues to predict the possibility of the occurrence of injury and prevent injuries deduced by remarkable asymmetry using gait analysis. Seiji Matsubara, a PhD student and PT, collected biomechanical data from more than 200 uninjured and injured athletes for gait analysis to identify asymmetry in the lower limbs. Figure 7 presents the results from this preliminary analysis, which indicates several asymmetries, even in the uninjured athletes; in the hip adduction at the instant of the foot-flat, hip flexion at the mid-stance, and the knee internal rotation at the toe-off and mid-swing, as some investigators have pointed out.

4) A solution to the closed loop problem: Measurement of force and moment exerted on an instrument by each hand in hitting sports.

A closed loop is made by an instrument and upper extremities in hitting sports, such as baseball batting and golf. In the closed loop problem, there are insufficient equations and indeterminacy arises. The most effective, but technically difficult, solution to the closed loop problem is to measure forces and moments exerted by each hand separately using a well-designed instrumental device. Dr. Koike developed an instrumental bat and golf clubs to solve the closed loop problem in baseball batting and golf swings, and collected kinetic data with them using the Vicon system. Analyzing force and moment patterns for several players, he found that there were remark-

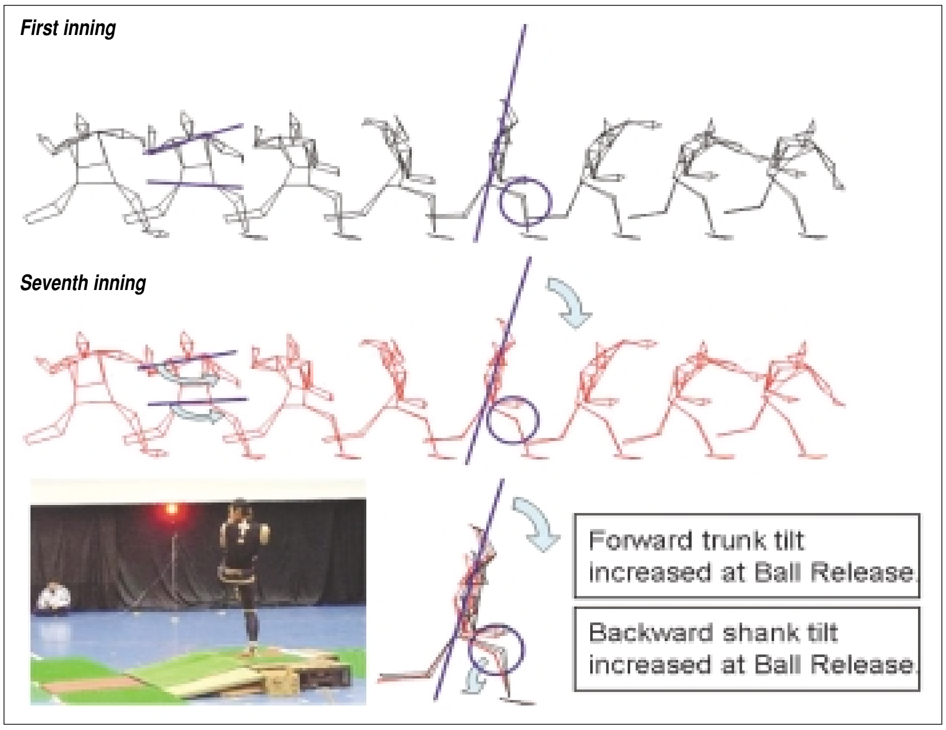
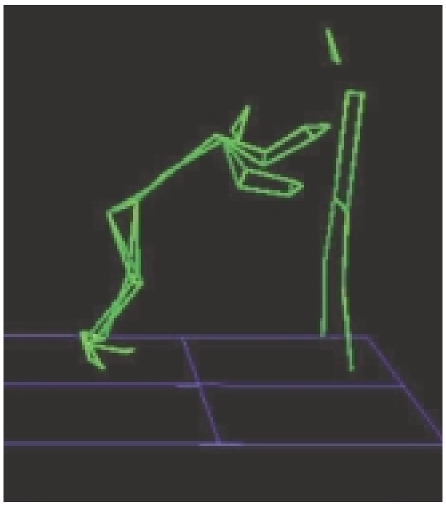


Figure 4
Data collection and analyses of baseball pitching under fatigued conditions are revealing changes in pitching motion from the first inning to the seventh inning, where the ball velocity gradually decreased.



◀ *Figure 5*
A Vicon output of SEOINAGE for an excellent Judo player.

able individual differences in these patterns. He will further investigate the kinetics of the upper extremities in hitting sports to understand the mechanism of swing motion and provide information for injury prevention.

In addition to biomechanical research, we recently discovered that the Vicon system is very effective for analyzing sport techniques and for correcting technical faults peculiar to athletes. It is also useful for learning new techniques, together with the use of "Standard Motion" and computer simulation in the optimization loop. Alternating between theory and practice is vital in the study of sport biomechanics to make our dreams come true.

References

Ae,M. *et al.* (1997) A biomechanical method for the construction of a "Standard Motion" and the identification of essential motions by motion variability. Book of Abstracts of The XVIth Congress the International Society of Biomechanics, Tokyo,p.27.

Koike,S., *et al.* (2004) An instrumented bat for simultaneous measurement of forces and moments exerted by the hands during batting. The Engineering of Sport 5, 2:194-200.

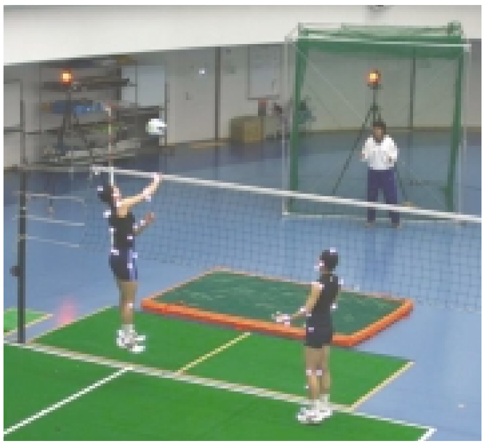


Figure 6 ▶
A female volleyball player spiking the ball set by the other player in which we investigated spike motion and a combination of the two players.

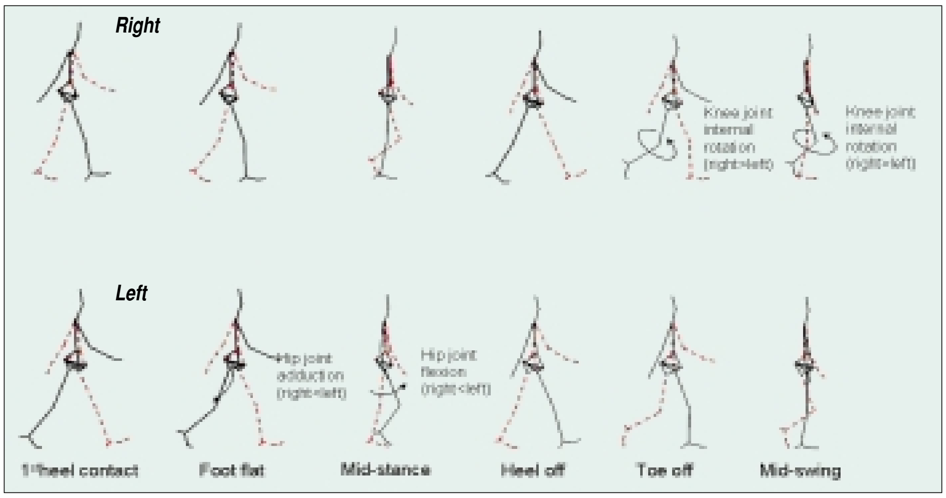


Figure 7 Asymmetry in the lower limb joints during gait for uninjured athletes.

ERGONOMIC RESEARCH:

Minimizing risk factors and developing training protocols for minimally invasive surgeons

by Gyusung Lee PhD, Ivan George, Rosemary Klein MA
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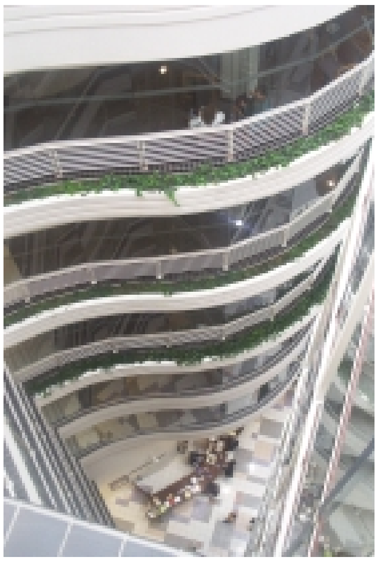
At the Minimally Invasive Therapy Center (MITC) at the University of Maryland Medical Center (UMMC), clinical and practical experts combine their knowledge of this patient-friendly surgical approach to achieve the best possible techniques and therapies.

This collaborative attitude has resulted in milestone achievements such as performing over 1,000 laparoscopic kidney removals from living donors and being among the first hospitals in the U.S. to combine minimally invasive coronary artery bypass surgery with stented angioplasty in the same operating room, which is both a fully equipped surgical suite and a state-of-the-art cardiac catheterization laboratory. Now research underway in the surgical ergonomics laboratory at our new University of Maryland Medical System (UMMS) Surgical Simulation and Technology Center aims for the evidence-based knowledge that will make laparoscopy a more surgeon-friendly and effective surgical approach.

Our ergonomic multi-phase, multi-site study of laparoscopic surgery – titled REVEAL (Reconstruction, Enhancement, Visualization, and Ergonomic Assessment for Laparoscopy) – has been designed to acquire data in regard particularly to medical students, residents and expert surgeons and their movements and skill levels as they perform minimally invasive surgical tasks. The data mined from the performances of these surgeons as they attend to sequential simulated surgical tasks,



The Surgical Simulation and Technology Center is located on the 7th floor of the South Hospital of the University of Maryland Medical System.

including Fundamentals of Laparoscopic Surgery (FLS) tasks, laparoscopic suturing, and other techniques, will yield crucial ergonomic information.

MIS involves working with long-shaft instruments, which require extreme positions of motion at the wrist and require greater instrument gripping forces than the traditional surgical instruments used in open surgery. In

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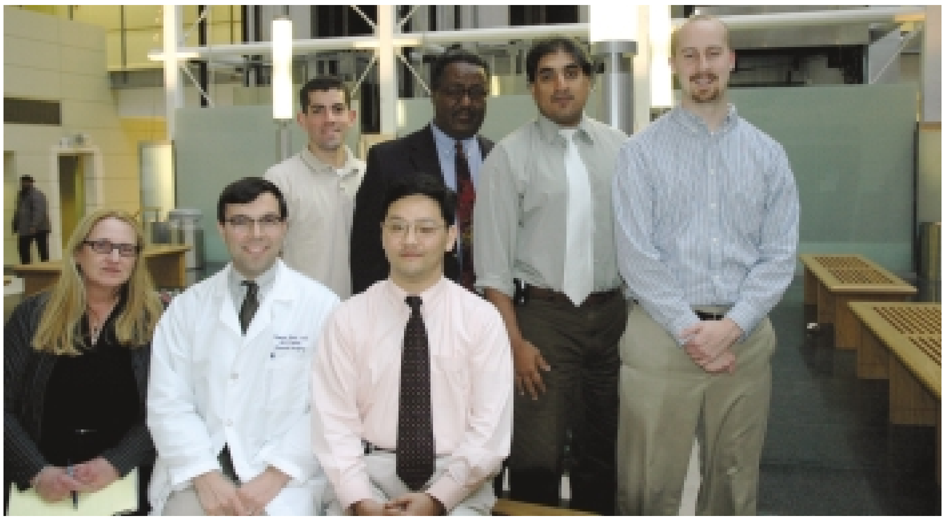

Research Committee: Standing left to right: Jesus Caban, Systems Analyst; Tsegay Baraki, Research Coordinator; Ivan George, Director of Advanced Technologies and Special Projects; Ethan Hagan, Multimedia Specialist; Rosemary Klein, Editor; Dr. Stephen M. Kavic, Advanced MIS Fellow; Dr. Gyusung Lee, Faculty Research Associate.

addition, because of the closed operative environment, the minimally invasive surgeon typically, must manipulate his or her instruments in 3D space while viewing that same work space in 2D on a video monitor that is not within the surgeon's natural line of sight. This creates postural conditions that are very different from those assumed during traditional open surgical procedures. As a result, laparoscopic/endoscopic surgeons, especially those who have been practicing MIS for a considerable duration, frequently experience fatigue and pain in the neck, upper extremity, back, wrists, and hands. Our research is designed to provide important information allowing us to identify the ergonomic risk factors inherent in particular surgical movements associated with MIS. Initially we have set out to determine what specific movement patterns occur during particular surgical tasks. Knowledge of specific movement patterns and how those patterns are affected by surgeon experience and/or skill level allows us to identify key risk factors and evaluate whether equipment or training modification is needed. Furthermore, this information should prove beneficial in designing training protocols to minimize future injuries.

Surgical Ergonomics Laboratory

The UMMS Surgical Simulation and Technology Center's ergonomics lab, housed in what had been an operating room, is outfitted with a twelve-camera Vicon MX system. This Vicon optical motion capture system transcended operating room (OR) issues that other available, similar systems did not.

For instance, an interference issue in regard to metal objects in the OR environment excluded electromagnetic tracking systems, and the connecting wires of optoelectric marker systems would limit the movement of surgeons. We also appreciated that the Vicon MX uses both grayscale and edge detection to find marker centers since this capability can be used to capture the location of non-spherical markers, allowing, for instance, a band of reflective tape to be wrapped about the shaft of a medical instrument.

Our cameras, rather than being tripod supported or wall mounted, have been mounted onto a ceiling-level truss system. Each experiment has its own unique requirements, and our truss installation, which distributes our cameras in a minimum of space, greatly expands our structural ability to meet those requirements. In addition the truss system provides necessary flexibility as we can adjust camera location to focus precisely on particular areas of the body. In the middle of our Vicon MX optical motion capture system installation are two AMTI force plates.

Data is acquired in a variety of ways. The Vicon MX Control unit allows us to capture up to 128 analog channels. Through it, we collect force plate and EMG signals and synchronize them with motion data. In addition, we record three video images (two video camcorder images and an s-video endoscope image) and combine them using a Provideo MV-9 multi-view video system to create one

View of the operating room during a laparoscopic inguinal hernia repair.

DV output fed into a high-end Pentium-based dual-processor computer dedicated to our Vicon system. On that same computer we also employ a real-time data capture and processing feature using Vicon Workstation and Polygon. To monitor muscle activities during surgical movements, we also use a Delsys 16-channel Bagnoli electromyography (EMG) system.

Our lab uses three different endoscopic display systems: 1) a conventional CRT display fixed at the training tower, 2) an LCD display on a moving arm, and 3) a multi-projector display system. The distributed display system consists of six projectors that are casually aligned and self-calibrating and that utilize distribution processing systems and self-monitoring components. Our research, including performance measurement, cognitive examination, and biomechanical analysis will also test the impact such a system might have on surgeons' overall and ergonomic performance of MIS procedures.

CURRENT RESEARCH PROJECTS

We are using four of the five tasks – pegboard transfer, pattern cutting, endoloop placement, and suturing/intracorporeal knot tying–that comprise the Fundamentals of Laparoscopic Surgery (FLS) - the official examination program used by the Society of American Gastrointestinal Endoscopic Surgeons (SAGES)

Twelve Vicon MX cameras are used to track the surgeon in front of a high-resolution distributed display system.

Partial view of the ergonomics laboratory, showing Vicon MX cameras mounted on truss system, trainer station, and display systems.

in our experiments. In one recent experiment, seven right-handed surgeons with different levels of MIS experience were recruited to perform these four specific tasks. So that surgeons could maintain the correct elbow joint angle while holding surgical instruments at rest, the surgical trainer box was mounted on a height-adjustable platform. The surgeons stood with one foot on each force plate. A standard CRT monitor that displayed endoscopic images from a zero-degree scope was located at eye level in front of the participants. Wearing medical scrubs, the surgeons had 39 reflective markers placed on body landmarks so that their body movements could be reconstructed using motion capture technique. Marker placement followed the Vicon guidelines for the Plug-In-Gait model. Whole body movements were captured along with force plate data.

In another study, which used the FLS pegboard transfer task, joint kinematics – characterized by range of motion (ROM), mean joint angle (MJA), and mean joint movement amplitude (MJMA) – were correlated to performance time. Optimizing joint kinematics will most likely allow MIS surgeons to achieve better surgical performance. Our study revealed that MJA varied with different performance skill. Participants requiring the most time to perform showed more mean flexion angles ($r=.684$, $p<.05$) at the left elbow, while maintaining approximately 90 degrees at the right elbow. Regarding the left wrist, more skilled participants, requiring the least time, showed more external rotations ($r=.680$, $p<.05$) while less skilled subjects maintained the neutral position. Less skilled subjects showed more external rotation at the right wrist ($r=-.751$, $p<.05$). ROM and MJMA did not differentiate performance skill levels. This study suggests further investigations on joint movement patterns to formulate joint control strategies for optimal laparoscopic surgery training.

While previous studies in surgical ergonomics have shown that instrument usage, task difficulty, and subject skill level can be correlated to postural stability, the possibility that surgeons may strategically change their stance or joint movement to achieve better surgical outcomes while potentially subjecting themselves to greater kinematic risk has not been considered. In another of our

Dr. Patricia L. Turner, Assistant Professor of Surgery, performing FLS task at trainer station.

studies, one highly experienced and skilled surgeon reported the development of carpal tunnel syndrome in both of his wrists. Still, this participant was able to finish both the FLS pegboard transfer and pattern-cutting tasks significantly faster than others. To minimize wrist flexion during the pegboard transfer task, the surgeon increased the abduction angle of his shoulder so that his hand and forearm aligned. During pattern cutting, the subject maintained his lower body position and stance while twisting his torso in a strategy that appeared to stabilize a tangential direction in relation to the cutting while maintaining a fixed orientation of forearm, wrist, and hand. In a different trial when circle-cutting was the task, the subject changed his stance primarily by shifting foot position as needed in order to obtain better approach angles for the scissors. These compensatory and strategic movements caused increase in his overall postural sway, yet they did not necessarily represent postural instability.

This case study demonstrated that poor postural stability or joint kinematics do not necessarily correlate to poor performance but may instead be positive compensatory or strategic movements. Therefore, background information about participants, which might, for instance, include joint impairment, should be considered as an important ergonomic element, the correlation of which may lead to more accurate and specific conclusions about optimal postural stability and joint kinematics for minimally invasive surgeons.

CUSTOM DEVELOPMENT

While most gait, neuroscience or other motion analysis laboratories have quite a bit of open space between cameras and subject, MIS operating rooms, also referred to as surgical endo suites, consist of a number of elements (surgery table, medical instruments, anesthesia machines, nurses and assistants) that may be

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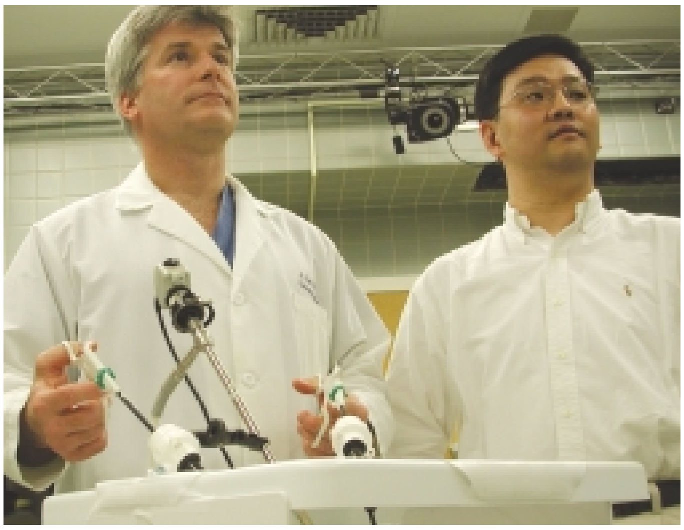
Dr. Kavic offers a clinical interpretation of the biomechanical data to Dr. Lee.

located chronically or statically between markers and cameras. Therefore, conventional methods, such as a Plug-In-Gait marker set, of attaching tracking markers to surgeons is almost impossible in this environment. To overcome this problem, we are, as part of our research, developing custom marker placement using clustered markers. For better data capturing, three or four markers are grouped together and attached to a body segment toward which the cameras are pointed. Following recent recommendations from the International Society of Biomechanics (ISB), a new kinematic model is being developed using Body-Builder language for use with new cluster marker placements.

SURGICAL TRAINING IN THE FUTURE

Currently when residents train at MIS trainer stations, how they move their bodies to achieve optimal instrumentation maneuvering is difficult for instructors to precisely monitor since they must depend basically on visual analysis and past experience. Those training protocols and guidelines that are used for evaluation are not likely to be defined quantitatively. When we have collected enough biomechanical data based on the joint movements, postural stabilization and muscle activation of expert MIS surgeons, it will be possible to create a set of standard matrixes to be employed in a variety of uses, including surgical training and safety. In the future we hope to create a new smart training system that can collect biomechanical data from an MIS trainee, compare this data to standard matrixes, and in real time notify an instructor immediately when a significant deviation is observed. Developing such a system will become possible when today's real-time processing becomes more advanced in hardware and software systems' features and in our custom programs. In terms of helping trainees learn optimal MIS maneuvering, this real-time monitoring/training system will be highly revolutionary, effective, accurate and time-saving.



Creating standard training and safety ergonomic matrixes is one of the most important outcomes sought by Dr. Park, Head of the UMMC Division of General Surgery, who directs the REVEAL Project at UMMC and Dr. Lee.

The History of Vicon

by Tom Shannon
Director of Operations

Examples of most equipment types have now been returned to their former glory and are on permanent display with documents, photographs, software and manuals in a small museum located in Oxford. Over the next few issues of *The Standard* I hope to re-visit and bring life to the many technical challenges, achievements and difficult decisions that helped to define and in some cases have driven the directions taken in our field over the past decades.

Beginnings

Hans Furnée, PhD of the Technical University at Delft in The Netherlands is generally considered to have been the first researcher to present results that demonstrated the use of video images displaying reflective anatomical markers. His experiments during 1967, measuring in two dimensions, the joint ankles of a cat running on a treadmill were a portent to the future widespread adoption and dominance of optics and electronics to measure the kinematics of motion. In the early 1970s, Dr David Winter then of the University of Manitoba, Winnipeg was also actively involved in the development of video based kinematic data collection systems, further strengthening the approach in North America.

Professor John Paul of the University of Strathclyde in Scotland built on Dr Furnée's seminal work by applying two research students to the task of achieving three dimensional movement analysis using multiple cameras. In 1972, students Mick Jarrett and Brian Andrews started their doctoral studies and achieved a working system based on a Digital Equipment Corporation (DEC) PDP-12 computer. In 1980 Brian Andrews continued the development using a later model computer; introduced shutters to the cameras to minimise marker smear from moving objects, and implemented the application of strobed lighting with video cameras to illuminate reflective markers.

The current Deputy Chairman, Julian Morris DPhil, became aware of the work at Strathclyde in 1973 and as a researcher at the Nuffield Orthopaedic Centre, University of Oxford, was keen to collaborate to set up video based gait analysis facilities in a number of British hospitals. During 1974-75, Julian arranged for an electronics engineer friend, Malcolm Herring, to re-design the prototype, and subsequently three systems were produced for Strathclyde and the Universities of Dundee and Oxford.

The First Vicon Systems

In 1977, Julian left the Nuffield Orthopaedic Centre to pursue a career in industry. He became the Technical Director of Oxford Medical Systems (part of the Oxford Instruments Group) specialising in products aimed at cardiology but continued to believe that there was a commercial market for an automated 3D gait analysis system. He was able to licence the existing technology and over the next two years gathered a development

Tom Shannon

Founders of Oxford Metrics Limited (1984)
L-R:
Annabel MacLeod (Applications Engineer), Dave Knopp (Software Engineer), Graham Klyne (Software Manager), Julian Morris (Managing Director), Tom Shannon (Engineering Manager). Absent: Edi Cramp (US Customer Support).

In the normal course of events, a rare visit to a stock room filled with old, dusty and obsolete equipment would not be a source of much inspiration. As an amateur historian, more used to poring over ancient documents, maps and photographs, I saw that these modern relics represented not only milestones in a journey made by a small number of highly talented people, but were also closely and intimately entwined in the development and routine use of equipment to automatically measure human and animal motion.

team together to redesign the Vicon (the name derives from video-converter) hardware, and to develop the first 3D photogrammetry data capture software by drawing on the published works of many including Herman Woltring. In 1980, the first system was shipped to Eric Radin, MD in West Virginia and a few months later a second to Dr Sheldon Simon, MD at the Boston Children's Hospital.

Gait Analysis

Michael Whittle, MD, PhD replaced Julian Morris in the role of the director of the Motion Laboratory at the Nuffield Orthopaedic Centre upon his return to the United Kingdom. After three years working with NASA in Houston supervising musculoskeletal experiments on the Skylab Space station, his PhD dissertation focussed on the 3D measurements of an astronaut's body form. Dr Whittle was able to use this unique experience to develop clinically useful motion capture software using data from the Vicon system.

In 1982, Dr Jarrett worked with Dr Simon's Vicon system, perfecting software for clinical applications as did Dr Ed Biden of the San Diego Children's Hospital Gait Laboratory after a system was purchased in 1984.

Murali Kadaba, PhD joined the Helen Hayes Hospital in the United States as a research scientist in 1979 and became interested in the reproducibility and reliability of gait data. He expanded his research to include the numerical representation and pattern recognition of both kinetic and kinematic data that led by 1985, to the development of dedicated clinical software using standardised marker positions.

My list is far from exhaustive but rather helps to demonstrate how early adopters were using commercially available capture technology to satisfy very specific clinical needs.

Changes

In 1984, the Oxford Instruments Group decided to become a public company and to concentrate on its core business, being the manufacture of cryogenic magnets for Magnetic Resonance Imaging. The biomechanics side of the business was sold to Julian Morris, other members of the development team and the author. The new business was named Oxford Metrics Limited, with the remit to continue the development and marketing of the Vicon system together with investigating the application of surface topography to the assessment of progression of spinal deformities in children.

By the middle of the 1980s the Vicon system was established as a tool for use in biomechanics research, ergonomics and as the apparatus to capture gait data in a clinical setting. The time was right to make a new technological jump.

In the next issue, I will address the rise of the concept of the datastation, three-dimensional identification and tracking and the focus on the development of dedicated clinical management software.

[Early history derived from Sutherland D H "The evolution of clinical gait analysis Part II Kinematics: Gait & Posture 2002; 16: 159-179."]

Early Vicon RSX brochure 1985

MEETING POINTS ...

American Academy of Cerebral Palsy & Developmental Medicine (AACPDM) East European & Mediterranean Meeting from June 8 to 10, 2006 at the Marriott Hotel, Warsaw, Poland; the 10th International Child Neurology Conference at the Bonaventure Hilton, Montreal, Canada from June 11 to 16, 2006; the AACPDM Annual General Meeting from September 13 to 16, 2006 at the Boston Marriott Hotel, Boston, Massachusetts, USA (preliminary program available in June), and the European Academy of Childhood Disability from October 19 to 21, 2006 at the Hotel Serhs Campus, Barcelona, Spain (Abstracts deadline May 25, 2006). For information on these events see *www.aacpdm.org*

American Academy of Kinesiology & Physical Education "Academic Discipline of Kinesiology" Conference from September 14 to 16, 2006 at Westward Look Resort, Tucson, Arizona, USA. *www.aakpe.org*

American Academy of Orthotists & Prosthetists The 2007 Annual Meeting in San Francisco, USA will be held from March 21 to 24. Details on *www.oandp.org* or contact Diane Ragusa *dragusa@oandp.org* (703) 836 0788 ext 208.

American Academy of Physical Medicine and Rehabilitation (AAPMR) The 67th Annual Assembly will be at the at the Hilton Hawaiian Village Convention Center, Honolulu, from November 9 to 12, 2006. In 2007 it will be in Boston Massachusetts, USA at the Sheraton Marriott Hilton Hynes Convention Center from September 27 to 30, and in 2008 at the Marriott Convention Center, San Diego, California, USA from November 20 to 23. Information on *www.aapmr.org*

American Academy of Podiatric Sports Medicine The Annual Meeting in August 2006 is to be held in Las Vegas, Nevada, USA. Information, as it becomes available, on *www.aapsm.org* or contact Rita Yates (888) 854-FEET; e-mail *info@aapsm.org*

American College of Sports Medicine The 53rd Annual Meeting in 2006 is in Denver, Colorado, USA from May 31 to June 3. Program and other details on *www.acsm.org/meetings*
The 54th Annual Meeting is currently planned for New Orleans, USA from May 30 to June 2, 2007.

American Alliance for Health, Physical Medicine & Rehabilitation National Convention in 2007 is from March 13 to 17 in Baltimore, USA. Presentation submissions by July 15, 2006. Information *on www.aahperd.org*

American Orthopaedic Association 119th Annual Meeting in 2006 is from June 21 to 24 at the Westin Cantara Resort, San Antonio, Texas, USA. *www.aoassn.org*

American Orthopaedic Society for Sports Medicine (AOSSM) 32nd Annual Meeting is being held from June 29 to July 2, 2006 at the Lodge & Convention Center, Hershey, Pennsylvania, USA *www.aossm.org*

American Physical Therapy Association (APTA) The APTA Annual Conference 2007 will be held from June 27 to 30 in Denver, Colorado, USA.
APTA website *www.apta.org*

American Podiatric Medical Association The Annual Scientific Meeting in 2006 will be from August 7 to 10 at MGM Grand, Las Vegas, Nevada USA.
Main website *www.apma.org*

American Society of Biomechanics The next Annual Meeting will be from September 6 to 9, 2006 at the Virginia tech – Wake Forest School of Biomedical Engineering & Sciences, Blacksburg, Virginia, USA.
Meeting website is *www.asb2006.org* or e-mail for information to *aliceb@vt.edu*
The Society website is *www.asb-biomech.org*

American Spinal Injury Association The 32nd Annual Scientific Meeting is at the Westin Copley Place Hotel, Boston, Massachusetts, USA from June 24 to 28, 2006. More details from *www.asia-spinalinjury.org/annualmeeting*

Association of Academic Physiatrists (AAP) 44th Annual Educational Conference will be from April 10 to 15, 2007 at the Caribe Hilton, San Juan, Puerto Rico. Details from Lynn Lawson, e-mail *lylawson@physiatry.org* Telephone (317) 431 3368; Fax (317) 823 9950.
Main website *www.physiatry.org*

Association of Children's Prosthetic and Orthotic Clinics The 2006 Annual Meeting, from May 17 to 20, will be at the Hyatt Regency in Sacramento, California, USA. The Shriners Hospital for Children will be the host clinic. Information by e-mail from *raymond@aaos.org* Telephone (847) 698 1637; Fax (847) 823 0536.
The main website is *www.acpoc.org*

Australian Association of Exercise & Sport Science Biennial Conference will be from September 28 to October 1, 2006 at the University of New South Wales, Randwick Campus, Sydney, Australia. *www.aaess.com.au*

Australian Physiotherapy Association The 2006 National Congress is being held May 26 and 27 at Sofitel, Melbourne, Victoria, Australia.
www.apa.advsol.com.au Main website is *www.physiotherapy.asn.au* Telephone (03) 9536 9335; Fax (03) 9534 9199.

Canadian Association of Prosthetists & Orthotists (CAPO) The CAPO 2006 Convention is from August 16 to 19, 2006 at the Lakefront Resort & Conference Centre, Kelowna, British Columbia, Canada. Information from Kathy Kostycz, e-mail *capo@mts.net* or telephone (204) 949 4970; fax (204) 947 3627; or on main website *www.pando.ca*

Canadian Physiotherapy Association The 2006 Congress will be held from June 30 to July 2 at the Delta St John Hotel & Conference Centre in St John, New Brunswick, Canada. Information from *www.physiotherapy.ca/congress2006*

Canadian Society for Biomechanics The 14th Biennial Conference, from August 16 to 19, 2006, will be at the University of Waterloo, Waterloo, Ontario, Canada. See *www.csb2006.uwaterloo.ca* or main website *www.health.uottawa.ca/biomech/csb/*

European Orthopaedic Research Society The next EORS Congress will be June 7 & 8, 2006 at the Istituti Ortopedici Rizzoli, Bologna, Italy.
Information by e-mail from *fisiopat@ior.it* and the website *www.ior.it/eors06*

European Society for Movement Analysis in Adults & Children (ESMAC) The 15th Annual Meeting is also the First Joint ESMAC/GCMAS meeting (GCMAS 11th Annual Congress) and will be in Amsterdam, Netherlands from September 25 to 30, 2006. Early registration date is June 1, 2006. More information from *j.harlaar@vumc.nl* The 2007 Meeting is planned for Athens, Greece. The main ESMAC website is *www.esmac.org*

International Ergonomics Association The IEA 2006 16th Congress takes place from July 10 to 14 in Maastricht, Netherlands. *www.iea.cc*

International Federation of Sports Medicine (FIMS) The FIMS World Congress of Sports Medicine in 2006 will be at the International Convention Center, Beijing, China from June 12 to 16. Information from the National Research Institute of Sports Medicine in Beijing – telephone +86 (10) 6719 2750; fax +86 (10) 6719 2755; e-mail *ligp@263.net*
The FIMS website is *www.fims.org*

International Society of Biomechanics XXIst Congress will be from July 1 to 5, 2007 at the International Convention Center, Taipei, Taiwan. Information being compiled on *www.isb2007.org*
The ISB website is at *www.isbweb.org*

International Society for Biomechanics in Sport The next International Symposium will be from July 14 to 16, 2006 at the University of Salzburg, Austria. Telephone +43 662 8044 4884; fax +43 662 6389 4884.

Information from *isbs2006@sbg.ac.at*
Main ISBS website *www.isbs.org*

International Society of Electrophysiology & Kinesiology
The XVI Congress will be held at the Lingotto Congress Center, Torino, Italy from June 28 to July 1, 2006. There will be a pre-Congress Workshop on June 28 and a post-Congress Course on Movement Analysis in Sport and Exercise on July 3 & 4 at the University Institute for Movement Sciences in Rome. Information from *www.isek2006.it*
The main website is *www.isek-online.org*

International Society of Physical & Rehabilitation Medicine (ISPRM)
The 4th International Congress from June 10 to 14, 2007 is to be in Seoul, Korea and the 5th will be held in Istanbul, Turkey. More information will become available at the Society's website *www.isprm.org*

International Society of Postural & Gait Research The 2007 Conference is planned for Baltimore, USA. Information, as it becomes available, on *www.ispgr.org*

International Society for Prosthetics & Orthotics The 12th ISPO World Congress is to be held from July 29 to August 3, 2007 at the Vancouver Convention Centre in Vancouver, Canada.
Information from the ISPO Congress website *www.ispo.ca/congress* or from 1- 604 681 5226 e-mail *ispo2007@venuewest.com* Meanwhile the UK National Member Society for Prosthetics & Orthotics is holding the next Annual Scientific Meeting in the UK on November 3 and 4, 2006 at the Moat House Hotel, Stoke-on-Trent, Staffs, England. Abstracts submission June 16, 2006. Details on *www.ispo.org.uk* or e-mail *info@ispo.org.uk* Telephone +44 (0) 141 560 4092 (Irene Cameron).

Japanese Orthopaedic Association
The 79th Congress will be at the Pacifico Yokohama from May 18 to 21, 2006. Information e-mail *office@joa.or.jp*
Congress website *www.joa2006.com*.
The Association's 21st Annual Orthopaedic Research Meeting from October 19 to 20, 2006 will be at Brick Hall, Nagasaki. Meeting website *www.congre.co.jp/kiso2006/*
The 18th Annual Skeletal Dysplasia Meeting is planned for December 2, 2006 in Fukoaka and the 80th Congress for Mar 24-27, 2007 at Kobe International Conference Center. The Association website is *www.joa.or.jp*

National Athletic Trainers Association (USA) The 57th Annual Meeting & Clinical Symposia is planned for New Orleans from June 27 to July 1, 2006 and in 2007 from June 26 to 30 in Anaheim, California, USA. Information, as it becomes available. from *www.nata.org*
North American Society for Pediatric Exercise Medicine The next Biennial Conference from September 13 to 16, 2006 is at the University of South Carolina, Charleston, S Carolina, USA.
See *www.naspem.org*

Orthopaedic Research Society (ORS) – The 53rd Annual Meeting, to be held from February 11 to 14, 2007 will be in San Diego, California, USA. The 6th Combined Meeting of the Orthopaedic Research Societies, from October 20 to 24, 2007 is at the Hawaii Convention Center, Honolulu, Hawaii, USA.
See *www.ors.org* or e-mail *ors@aaos.org*

Scoliosis Research Society (SRS)
The 41st Annual Meeting is from September 13 to 16, 2006 (pre-meeting one day course on September 13) at the Monterey Conference Center, Monterey, California, USA. Information on SRS website *www.srs.org*

Society for Neuroscience The 36th Annual Meeting – is planned for New Orleans, USA in 2006 from October 21 to 25, and the 37th in 2007 from November 3 to 7 in San Diego, California, USA..
www.sfn.org

World Confederation for Physical Therapy The 2007 International Congress on World Physiotherapy will be from June 2 to 6, at the Vancouver Convention and Exhibition Centre, Vancouver, Canada. Abstracts submission by September 15, 2006. Information on *www.wcpt.org/congress/index.php*
The main website is *www.wcpt.org*

World Congress of Biomechanics will be held from July 29 to August 4, 2006 in Munich, Germany. Information on *www.wcb2006.org*

Additional sites of interest

American Academy of Pediatrics
www.aap.org
American Society of Exercise Physiologists *www.asep.org*
Bone & Joint Decade (2000-2010)
www.boneandjointdecade.org
British Association of Prosthetists and Orthotists *www.bapo.com*
Clinical Movement Analysis Society
www.cmasuki.org
European Paediatric Orthopaedic Society *www.epos.efort.org*
Gait & Clinical Movement Analysis Society *www.gcmas.org*
International Federation of Foot & Ankle Societies (IFFAS)
www.globalfoot.org
International Federation for Medical & Biological Engineering
www.ifmbe.org (Click on "Calendar")
International Organization of Physical Therapists in Women's Health
www.ioptwh.org
Ontario Kinesiology Association
www.oka.on.ca
For **Physical Therapy** links through the University of Sydney
www.library.usyd.edu.au
For other events refer also to
www.gcmas.org/societies.html

Obituary:

Barry Goode

Born: 26 September 1949
Died: 10 February 2006

It's strange to speak of a close friendship with someone met on sadly few occasions, but Barry brought out the strange and wonderful in so many people he knew.

Like most others, almost all my meetings with Barry were on his home patch in Houston. He was not fond of travelling and was generally averse to the regular convergences of the gait analysis community. Happily, for a long period in the very early days of Vicon, as we explored the system's potential in the management of children with cerebral palsy, there were more than sufficient reasons to make regular trips to Houston. The caring and talented clinical team, then in their "old" hospital", were already achieving a lot and were completely confident of what they wanted and needed to do next. Behind this confidence was the support, devotion, and enthusiasm of an engineer who never chose academic acclaim but was complete master of his wide and varied subjects. If Barry suggested something, as he regularly did, you knew it was both possible and a goode idea.

Barry never shut down. The intensity of his enthusiasm hit you the moment you stepped off the plane and continued until, exhausted, you left town. He liked to try everything, whether it was a new arrangement of cameras in the lab, the latest processor to arrive at Fry's, or the entire range of beers on offer at the Ginger Man. (Our favourite was Old Foghorn.) He would blast music at you until something touched the spot as you hurtled down the freeway singing at the tops of your voices, too terrified to glance at the speedo.

The biggest surprise for an old European liberal was to find a common spirit in this larger-than-life Texan. I have no idea whether he made everyone feel the same way through his encompassing kindness and courtesy, but I know when we met after gaps lasting years, we would just pick up where we left off. It's very sad that it won't happen again.

Julian Morris

Sadly, as we go to press, we have just learned of the deaths of Dr David Sutherland and Dr Mary Wooton.

MOVEMENT CHALLENGES IN MULTI-JOINT REACHING TASKS

by James S Thomas, PhD., PT.,

Associate Professor, School of Physical Therapy,
Ohio University, W277 Grover Center, Athens Ohio 45701, USA

Reaching tasks such as ringing a doorbell, wiping a child's face or retrieving the morning paper require the control and coordination of the trunk and limb segments in order to perform these tasks smoothly and effortlessly. These reaching tasks are so common in our everyday experience, yet we rarely contemplate the complexity of such motor tasks or the variety of movement patterns we can utilize to perform them.

Conceptually, a reaching task could be parsed into a postural control task and a movement task which the central nervous system (CNS) must plan and execute. With respect to the reaching tasks described above, the CNS must solve two problems. One, the movement must be planned such that the projection of the center of mass (COM) is within the base of support after target contact. Two, the trajectory of the trunk and limb segments must be planned such that the hand can reach the intended target. Given the number of segments involved in these whole-body reaching tasks there are an infinite number of ways in which these tasks can be completed.

How then are reaching movements planned and executed? Are there rules by which the central nervous system (CNS) apportions the rotations of the limb segments involved in the task? How are these rules altered with orthopedic impairments? The goals of the Motor Control Laboratory at Ohio University are to 1) identify sets of rules (i.e. kinematic and kinetic) by which multi-joint tasks are governed by analyzing the segmental kinematics and kinetics of individuals performing whole body reaching tasks and 2) determine how orthopedic impairments alters those rules.

Figure 2

Control of Standing Posture

To maintain an upright posture (under static or quasi-static conditions) the projection of the COM must remain within the base of support (the area delineated by the feet). This task can be thought of as balancing a top heavy inverted pendulum. The inverted pendulum model has been used to accurately describe the movement of the COM in a variety of postural tasks. Postural equilibrium is maintained by active muscle contractions which keep the COM within the base of support in response to external forces such as gravity or imposed accelerations, and internal forces arising from focal movements of the limbs or trunk. For example, in a trunk flexion task, the movement of the trunk may be considered the focal movement and backward movement of the pelvis, a compensatory movement which maintains the center of mass within the base of support

Displacement of the COM caused by focal movement of the extremities or by the change in orientation of the trunk is often counteracted by muscle activity in other segments to minimize the destabilizing effect of the perturbation. A focal movement has two components. One is the static component, which is the gravitational effect of moving the position of the COM (of the moving segment). The other is the dynamic component, which is the effect of acceleration of body segments on the postural equilibrium. Therefore, the CNS must plan for both the final geometry of the limb segments and the acceleration of the limb segments in order to maintain balance. However, in a multi-joint system there is a variety of strategies that can achieve this.

Kinematically Redundant Systems

Starting from an upright standing posture and reaching for a target that requires some forward bending of the trunk can be accomplished in many different configurations of the trunk and limb segments due to the large number of joints involved in these reaching tasks. That is, there are more mechanical degrees of freedom than are strictly required to complete this task. This is the problem of kinematic redundancy articulated by Bernstein and is best illustrated by example. Consider a subject reaching for a target in the horizontal plane when motion is restricted to the shoulder and elbow (two degrees of freedom). Given that two coordinates can define a point in a plane, there is only one configuration of the limb segments that can be used to reach the target. Now consider that the wrist is free to move (a system with 3 degrees of freedom). There exists an extra degree of freedom, and therefore an infinite number of configurations of wrist, elbow, and shoulder can be used to reach the target. The question then is how does the central nervous system choose the orientation of the limb segments from an infinite number of choices?

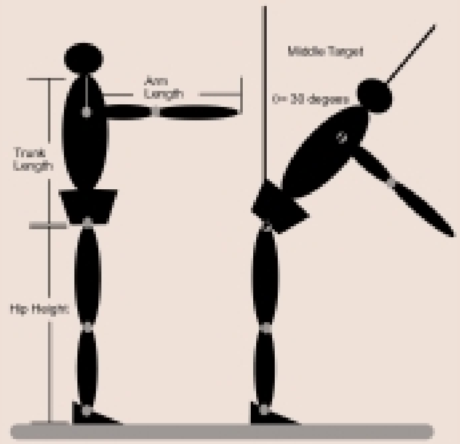


Figure 1

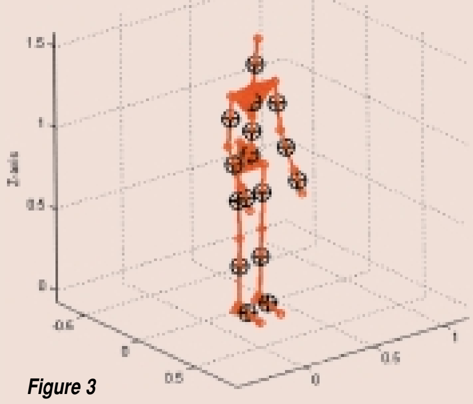


Figure 3

It has been hypothesized that the CNS resolves the problem of kinematic redundancy by reducing the independent degrees of freedom required to complete a given task. By imposing some rules by which coordinated movements are performed, complex multi-joint tasks are simplified. Several relationships have been identified for reaching tasks. These could be thought of as invariant features or characteristics of a movement task. One invariant feature identified in reaching tasks is that the spatial trajectories of the wrist are largely unaffected by changes in speed and load and that the velocity profile of the end effector tends to be bell shaped. Some have observed optimization of variables such as work, joint comfort, or combinations of work and joint comfort in subjects performing reaching tasks. Other relationships such as coupling between the shoulder and elbow joints have been demonstrated for circular drawing tasks and for reaching tasks. Fixed relationships of the trunk and limb segments have also been shown for rapid trunk flexion tasks and for kinematic patterns of gait. Whether these fixed relations are neural or mechanical in nature has yet to be elucidated, but it does suggest that the CNS might reduce the complexity at the kinematic level.

Alternatively, it has been proposed that the CNS may reduce the complexity of multi-joint tasks at the level of the dynamic joint torques. In this case the CNS issues a single command which leads to torques of similar time course at each of the joints. This in effect would simplify control of a multi-joint task.

Thus the evidence that the CNS plans at either the kinematic or kinetic level is

Figure 4

murky, and at the Ohio University Motor Control Laboratory the experiments are designed to continue to tease apart these two components.

Development of Reaching Task

To examine how people apportion motion to the various segments used in multi-joint reaching tasks, we have developed a paradigm that would 1) necessitate some forward displacement of the trunk to reach targets located in a mid-sagittal plane, 2) require progressively greater amounts of forward bending to reach each target location, and 3) standardize target locations to each individual's anthropometric characteristics (i.e., hip height, hip-to-shoulder length, and arm length). See Figure 1. Despite the fact that full body reaching tasks can be completed using an infinite number of movement patterns, our investigations of healthy subjects performing these tasks reveal certain commonalities across subjects, speeds, target positions and trial sequences. These commonalities were expressed as couplings of segmental motions. We have found that for any given standardized target location, healthy individuals choose to use either a "knee flexion/ankle dorsiflexion" strategy, or a "knee hyperextension/ankle plantar flexion" strategy. See Figure 2. Regardless of the movement strategy used, subjects revealed remarkably similar movement patterns of the lumbar spine and pelvis. Furthermore, when participants performed reaches at a fast movement speed, they used larger joint excursions of the ankle and knee but minimal change in spine motion. However, when motion is restricted at one joint due to pain, or fear of pain, the movement task can usually be completed, but the movement pattern will change (i.e. a change in inter-joint coordination). For example, when an individual with low back pain needs to perform a functional task that requires some motion of the lumbar spine (e.g. ringing a doorbell) they can compensate for reduced lumbar spine motion by increased excursions at the legs and the reaching arm. While the advantage of a kinematically redundant system is that function can be retained even with impairments, changes in motor coordination may prevent full recovery, precipitate re-injury, and are most likely moderated by levels of kinesiophobia. Thus it is critical to examine movement patterns in tasks that progressively challenge patients.

Ohio University Motor Control Laboratory

The Ohio University Motor Control Lab has seven MX13 Vicon cameras for kinematic data collection, two Bertec force plates to record ground reaction forces, and a 16-Channel Delsys EMG system. Analog data are captured with a 64-channel analog to digital board. We use Vicon Workstation software for camera calibration, data collection and post processing of kinematic data. All joint torques, forces, and power calculations are performed using Matlab Simulink. We have developed a full body 3D inverse dynamics model with 45 degrees of freedom (Figure 3). Thus we use the Vicon system to capture and process the kinematic data which is then used in our inverse dynamic model. The kinematic and kinetic data, along with the muscle activation data are used to derive sets of rules for control of multi-joint movements.

The laboratory is set up to support a variety of studies. The 20′ X 30′ dimensions of the room allow for collection not only of postural tasks, but also gait activities. The lab contains a 28′ runway, which gives us the ability to perform various gait or sport specific activities. The lab also contains a seating apparatus used to isolate trunk motion from the pelvis and lower extremities. This apparatus enables the experimenters to isolate specific trunk musculature while the subject performs maximal voluntary isometric contractions (MVIC). This method gives the experimenters a way to assess trunk strength and to have reference values for normalization of EMG data (Figure 4).

The Ohio University Motor Control Lab is funded through The National Institutes of Health (R01-HD045512) and the Ohio University Research Council. The key focus of the studies conducted in the Motor Control Lab revolves around central nervous system control of multi-joint movements in a kinematically redundant system and the influence of orthopedic impairments on that control. Specifically, as we identify sets of rules that govern control of multi-joint movements in healthy participants, we can test for shifts or changes in these rules with various impairments. Consistent with this notion, we are currently studying individuals with sub-acute or chronic low back pain, or those who have recently recovered from an acute episode of low back pain. The goal of the research is to understand the mechanisms of recovery and recurrence in low back pain. Future studies will use these reaching paradigms to assess treatment interventions on reducing the rate of recurrence in low back pain. This will ultimately provide clinicians with better evaluation and treatment criteria when confronting patients with low back pain.

Dr. James Thomas, PhD, PT, associate professor in the School of Physical Therapy at Ohio University, is the director of the Ohio University Motor Control Lab. Other key individuals in the day to day operations include Dr. Daohang Sha, a post-doctorate fellow, and seven graduate research assistants who are currently clinical doctorate students in the School of Physical Therapy. The lab group is shown in Figure 5.

Figure 5 Ohio University Motor Control Lab group. Back row: Dr Daohang Sha, James Odenthal, Tyler Bowersock, Kevin Swank, Stacey Moenter, Candice Kochman. Front row: Sara Clagg and Nikki Vander Wiele.

LITERATURE UPDATE

by Dr. Ed Biden,
Institute of Biomedical Engineering, University of New Brunswick, Canada.

When I began collecting possible papers for this Literature Update I came across three which were really intriguing in terms of their technology. The first deals with an interesting method to address marker dropout during data capture, the second is a new way to present motion data to reflect changes from the norm, and finally the third looks at gait as a means of identifying people by using some new measures which may be useful in classification.

Dockstader, S.L.; Imennov, N.S., **"Prediction for human motion tracking failures"** IEEE Transactions on Image Processing, Volume 15, Issue 2, Feb. 2006, pp 411-421 is not a light read and may be of most interest to the designers of tracking algorithms. In their very interesting literature review, the authors discuss the approach which has been most widely used in movement analysis, that of trying to improve tracking so as not to have missing markers. They reverse the problem, focusing instead on trying to predict when things will go wrong. This then opens up the opportunity to use models of the underlying body and its motions to rectify the problems before the failure occurs. I think their approach is applicable either at the data capture and reconstruction stage or as a means of "gap filling" once the data have been reconstructed.

The data they use for their examples are regular video images, but it is interesting that their example models of body configuration are almost exact analogs of the marker groupings used in Vicon for automatic marker labeling.

They begin with a 3D structural model of the body and in their examples use a Kalman filter as the prediction system. Kalman filters, in a simplified view, are simply models of the underlying system to be measured, against which the actual data can be compared and validated. In this case a "tracking failure" occurs when enough markers can no longer be tracked to be able to be sure of the movement of a particular segment. The novel part of their process is that they attempt to predict when the failures will occur so that they can begin to make adjustments prior to the markers actually disappearing. It is an interesting technique and they claim very positive results.

Manal, K., Chang, C., Hamill, J., Stanhope, S., **"A three-dimensional data visualization technique for reporting movement pattern deviations"**, J. Biomech, Vol 38 pp 2151-2156, 2005 describe a very interesting way of presenting motion analysis data. This is a good paper to read on a computer since it relies heavily on color, which I discovered only after I had printed it and taken it home for the evening.

The authors give a good background on how data are usually presented and describe time series techniques as well as angle-angle diagrams. Their technique, illustrated with a group of 15 normals and one clinical case, improves on traditional angle-angle plots by adding a third axis to represent time. By adding the time axis they can interpret the deviation of each component of the curve in terms of how many standard deviations it is away from the normal curve for angle vs time. They then map the deviations in terms of color so that the plots of a pathological case reflect how far the pathology moves the person away from the combined norms of the two angles being represented. The really nice thing about the technique, beside it seeming to be quite simple to implement, is that you can then preserve the colors when returning to 2D angle vs time graphs and use the color to tell how far the person is from normal curves.

The third technology paper is Ju Han; Bhanu, B. **"Individual Recognition Using Gait Energy Image"** IEEE Transactions on Pattern Analysis and Machine Intelligence, Volume 28, Issue 2, pp 316-322, Feb. 2006. These authors approach gait analysis from the point of view of trying to identify individuals. Their objective is to use gait as a "biometric" to identify people based on their movements. This is in the same spirit as systems that search for faces, or other characteristics. Their method is essentially to create silhouettes from a video of a person walking. These are indexed spatially so they are matched up, scaled for height, and averaged over time (usually a cycle). This creates a single image where segments such as the trunk and head are clear, and images of the limbs blurry because they are in different relative positions in each frame. The authors then use a pattern matching algorithm and report success comparable to other remote sensing biometrics methods in distinguishing individuals. This is probably the weakest part of the paper since they base this section on a fairly small amount of data which they have artificially adjusted to reflect variability in the population.

What struck me about this paper, is that the silhouette extraction is not terribly different from the identification of markers, which means it may not be a huge stretch to imagine a gait system doing the tracking. The other point is that if individuals can be distinguished based on normal walking then this technique may be very useful to distinguish and classify pathology. One could imagine a system that could generate the "gait energy image" and then use it to pattern match for various gait disorders. If such a system could track markers and the silhouette concurrently, it could then use the silhouettes to classify the problem and use a marker based calculation to measure only the variables of interest.

The second part of this review moves from new and interesting measurement and assessment methods to two interesting uses of very simple measures of gait. The first study: David, K., Sullivan, M., **"Expectations for walking speeds: standards for students in elementary schools"**, Pediatric Physical Therapy. 17(2):120-7, 2005 examined walking speeds of class groups of children as they moved in school hallways. They looked at a range of age groups from kindergarten to sixth grade and found that the walking speeds of the groups ranged from 1.1 m/sec (just under 4 km/hr), which is comparable to reported lab based walking speeds for kindergarten students, to 1.44 m/s (5.2 km/hr) for sixth grade. The 5.2 km/hr is actually quite a brisk pace and is faster than the 1.2 to 1.3 m/s which I think of as typical for adults.

The authors then had teachers walk at speeds which they felt were "good enough" walking speeds to accommodate children with movement limitations. These results fell in a much narrower range, clustered very closely around 0.85 m/s (3 km/hr) but are actually still within a range which would not be considered particularly slow. The value of such measures is that they have the potential to provide benchmarks for accommodation of children with movement limitations.

The second paper which touches on walking speed is: Cesari, M., Kritchevsky, S., Penninx, B., Nicklas, B., Simonsick, E., Newman, A., Tylavsky, F., Brach, J., Satterfield, S., Bauer, D., Visser, M., Rubin, S., Harris, T. Pahor, M., **"Prognostic Value of Usual Gait Speed in Well-Functioning Older People"** *Journal of the American Geriatrics Society*, Vol. 53 Issue 10, p1675-1680, 2005. This report is part of a very large Health Ageing and Body Composition Study and actually made measurements in over 3000 adults with an average age of 74 years and with follow-ups on health status averaging nearly five years. Walking speed tests were done by timing over a 6m walkway. The authors found that approximately 1 m/s (3.6 km/hr) was a critical division point. People in the study who walked slower than this rate were at significantly higher risk for developing health problems than were people who walked at more than the 1 m/s rate. I was struck by how such a seemingly small change, of about 20% less than typical adult speeds, was predictive of health outcomes.

I think these papers show that there is substantial potential for movement analysis techniques to develop in new and valuable ways and at the same time demonstrate that very basic measures continue to have tremendous value.

VICONPEAK
OMG 3D from the moving image

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