Associate Professorship of Sport Equipment and Sport Materials
TUM Department of Mechanical Engineering Technical
University of Munich

Annual Report 2017

Jahresbericht 2017

Sport Equipment and Materials

Sustainable support for sports and health through technology

TUM's broad knowledge from very different scientific disciplines helps us to realize our chosen holistic approach to better understand the interaction between athlete, equipment and environment. In 2017 we extended our internal network starting a close collaboration with the Chair of Micro Technology and Medical Device Technology (MiMed) of Professor Lüth.

From our 2017 activities four highlights are worth mentioning:

- Development and realization of a new test bench to quantify ski boot flexibility.
- Co-organization of 23rd University Day of the German Society of Sport Science 'Innovation & Technology in Sports' held at TUM.
- Intensification of our collaboration with Reutlingen University on the field technical garment and wearables. Common student project at Environmental Research Station 'Schneefernerhaus' (Zugspitze).
- Start-off R&D project (ZIM) realizing non-invasive real-time measurement of core temperature integrated into ballistic police helmets.

Towards Better Performance with Optimized Sport Equipment

Mountain bike downhill on a (widely) standardized track with two different suspension settings (photo: Lars Scharl)

Improving the performance in both top-level and leisure-time sports is one motivation of our work. The focus is on optimizing the energy transfer between athlete and equipment and on reducing the inherent energy loss. On the equipment level we try to achieve this by:

- better weight to stiffness ratio (i.e. bicycle frame),
- using energy storage and return effects,
- optimized heat- and moisture management of sport garments (i.e. new infills for down jackets),
- improved fitting to the individual (i.e. golf shaft).

An excellent example of our efforts towards optimized performance of sport equipment is demonstrated in a study which has been performed by one of our Master students (Pablo Weber, 2017). The goal was to characterize different suspension settings of mountain bikes and to answer the question if these have an influence on the perceived subjective riding experience of advanced bikers. Using a special suspension-tuning system (ShockWiz™) the performance of four identical enduro mountain bikes were tuned differently thus achieving

Data logger and linear displacement measurement at rear suspension (photo: Lars Scharl)

response characteristics such as ‘aggressive’, ‘efficient’, ‘balanced’ and ‘playful’.
All test bikes and their suspensions were equipped with sensors – standardized measurements on a test bench confirmed physically measurable spreads of the four setups. To answer the above question on the relationship between objective and subjective parameters a blind test was performed. The selected ten subjects – all at with approximately the same body weight had to rate the performance of the bikes under widely standardized field conditions and always against the same reference bike. Variance analyses confirm significant differences in perception and evaluation, thus paving the way for further research on mechatronic suspension systems.

Improved Fitting Through Customized Sport Equipment
A good core stability has a high impact in different fields of physical activity like rehabilitation, performance improvment and injury prevention. Especially during fast distal segment movements and initiation of force development, high activity and hence stability of the core muscles is essential.

Custom built data logger to measure cycling speed, displacements and velocities at the suspensions, three axis accelerations, angular displacements and velocities

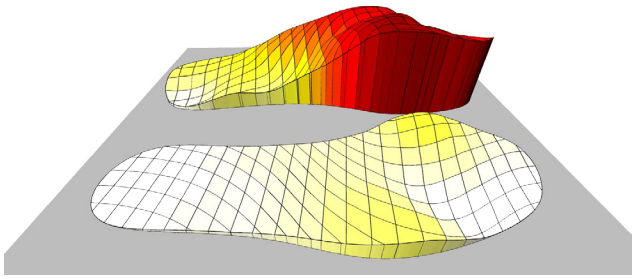
Through a holistic activation of hand- and arm muscles we want to achieve an equal activation of essential core muscle groups and therefore improve athletic performance. We aim to develop an individualized exoskeleton-glove that activates the aforementioned muscles.
A high level of manufacturing quality for these gloves is possible through our collaboration partner, the Chair of Micro Technology and Medical Device Technology (MiMed) of Professor Lüth. State-of-the art additive manufacturing techniques will be used to create these gloves. Using our expertise in scientific methodology, we will validate their efficacy in performance during a subsequent validation study.

First steps towards an individual exoskeleton-glove which aims to activate specific muscle groups to enhancing core stability

Future Aspects
Like the idea of ‘individualized medicine’ assistive devices (e.g. ortheses) should also be adjustable to an individual’s anthropometry. While ortheses and prostheses manufacturers already consider different segment circumferences and lengths, they still neglect individual differences with respect to the joint’s trajectory of its instantaneous centers of rotation, leading to uneven pressure distribution of the orthesis and consequently to high loads on soft tissues. Through high-precision measurement of human surface and joint properties, and additive manufacturing, we aim for a real customization for everyone in the near future.

Understanding the Interaction between Athlete, Equipment and Environment

Psycho-physics has pervasive and significant practical applications in different fields such as neuroscience, robotics but also for sports engineering. The meaning for sports engineering becomes clear if we look at the factor '(dis)comfort'. This variable is considered as one of the important criteria for athletes selecting and tuning their sport equipment. It may also have an impact on sport injuries and performance. One related question is whether there is a relationship between objective bio-mechanical parameters (i.e. plantar pressure distribution or joint angles) and the perceived ratings of the athletes. Running and especially on various type of terrain offers perfect boundary conditions to investigate this question. Systematically different types and levels of perturbations are imposed to runners (i.e. additional weight in the boots) and their perceptions of perturbations are gathered. Simultaneously objective variables such as center of pressure, vertical force, joint kinematics and EMG are measured. First observations indicate that the athlete seems to maintain his/her running pattern even if major equipment modifications have been made.



Plantar pressure measured with insoles

Rather non-ergonomic data collection in the field

Performance tests with subjective ratings of discomfort of different trial running shoes

Health, Wellness and More Fun Through Technical Support

Fitness Tracker GARMIN vivosmart® HR

Multisport watch GARMIN Forerunner® 920XT

Sports and physical activity are often considered as 'the preventive medicine not taken'. Clearly, this puts emphasis on the so-called self-management of health since people are individually responsible for their physical activity and well-being. Today, the advancement of sensing technologies, embedded systems, wireless communication, nano-technologies and miniaturization potentially makes it possible to develop smart systems for monitoring activities and vital parameters. In the last few years, a multitude of wearable devices, such as activity trackers, smart watches or inertia sensors have come to the market. They assist as a virtual coach, monitor physiological parameters or even serve as a feedback system. The future of wearable devices with sensors close, on or even in the body seems to be bright.

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Sports engineering not only takes care of developing those systems or improving their accuracy and usability. It is also in charge to validate them against gold standards. Regarding these issues, we are currently focusing on the validation of some current state wearable devices, e.g. multisport watches (GARMIN Forerunner® 920XT, Polar V800) and fitness trackers (GARMIN vivosmart® HR, TOMTOM Touch, Fitbit Charge 2, Withings Pulse Ox). The aim of this extensive study is to determine the accuracy of estimation of certain physiological parameters. These parameters include heart rate, energy consumption, the body fat percentage as well as the cardiorespiratory fitness level. Based on the results, the estimation of physiological parameters of future wearable devices shall be improved. In addition to that, we are also working on the development of new non-invasive measurement systems monitoring hydration status and glucose concentration.

Fitness Tracker Withings Pulse Ox

More Safety with Improved Protection Gear

In alpine skiing, knee injuries remain a major safety issue. Systematic analysis of injury situations and human anatomy suggest that mechatronic ski bindings may provide a solution. The key aspect of mechatronic ski bindings is the release algorithm. Two of the needed parameters of that algorithm are the knee angle and the muscle activity of the leg while skiing. Both parameters help to identify critical situations, which might lead to an increased risk of a knee injury. The algorithm would react by accordingly adjusting the release settings of the ski binding. Besides the research to establish the algorithm(s), we also have to develop functional close-to-body measurement systems being able to provide real time data on knee kinematics and muscle state of the skier. In collaboration with University of Applied Sciences Reutlingen we have developed a prototype of skiing underpants which are able to measure the knee angle.

We also work on the integration of sensors to register the level of the major leg muscles' activity.

Ski underwear with textile integrated sensors to measure knee flexion angle

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Research Focus
- Improved performance of sport equipment
- Safety and protection gear to avoid overloads
- Thermo-physiology in sport garment design
- Footwear – sport surface interaction
- Electric and muscle-powered lightweight vehicles

Competence
- Muscular-skeletal models and simulation
- 3D-motion analysis (optical, inertia, DGPS)
- Electromyography (EMG) and spirometry
- Measurement of external loads and plantar pressure
- Development of physical models (foot and ankle, knee, lower leg)

Infrastructure
- Mobile skin- and core-temperature measurement
- Multi-body simulation software SIMPACK®
- Mobile EMG and spirometry
- Video-based motion analysis (Simi Motion)
- Leg surrogate with loading device
- Instrumented bicycle
- 5-axis fatigue testing device for bicycle frames
- Skiboot flexibility test rig, simulating real ground reaction forces

Courses
- Basic Skills of Science
- Applied Biomechanics
- Sports Technology
- CAD-Basics
- Practical Ergonomics
- Digital Human Modeling
- Advanced Biomechanics
- Sports Engineering
- Interdisciplinary Research Project

Publications 2017

- Keshvari, B., Senner, V., Kraft, D. & Alevras, S. (2017). Comparative Study of Shoe-Surface Interaction in Trail Running – Subjective and objective Evaluation. In Proceedings of the 35th International Conference on Biomechanics in Sports (ISBS) 2017 (Volume 35, Issues 1)
- Keshvari, B., Mitternacht, J. & Senner, V. (2017). Competitive study of stud characteristics on the penetrability. Footwear Science, 9(sup1: Proceedings of the Thirteenth Footwear Biomechanics Symposium), pp. 60-61. https://doi.org/10.1080/19424280.2017.1314338
- Schwirtz, A., Mess, F., Demetriou, Y. & Senner, V. (Eds.). (2017). Innovation & Technologie im Sport. 23. dvs-Hochschultag München 13.-15. September 2017. Schriften der Deutschen Vereinigung für Sportwissenschaft: Vol. 265. Hamburg: Feldhaus Verlag GmbH &Co. KG. Retrieved from www.dvs2017.de
- Supej, M. & Senner, V. (2017). Special Design of Ski Plates May Improve Skiing Safety. In I. Scher, R. Greenwald, & N. Petrone (Eds.), Snow Sports Trauma and Safety. Conference Proceedings of the International Society for Skiing Safety (21st Volume, pp. 95-107). Springer International Publishing. https://doi.org/10.1007/978-3-319-52755-0_8
- Supej, M., Senner, V., Petrone, N. & Holmberg, H.-C. (2017). Reducing the risks for traumatic and overuse injury among competitive alpine skiers. British Journal of Sports Medicine, 51(1), 1–2. https://doi.org/10.1136/bjsports-2016-096502

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