Sport Equipment and Materials Group

R&D in sports technology combining engineering, sports science and computational methods

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Our main ambition in 2014-15 was to submit two major research proposals for funding; one on mechatronic ski bindings at the German Research Council (DFG) and the other (in collaboration with our TUM Institutes of Automotive Technology and Metal Forming and Casting) on innovative production technologies to receive financing by the Bavarian Research Foundation.

From our 2015 research activities four highlights are worth mentioning:

- ispo Brand New Award for our start-up 'tripstix' in the category Hardware Summer.
- Successful launch of heart rate control for electric bicycles.
- Artificial leg surrogate went into operation and shows human-like behavior.
- Start of an international collaboration with the Thermal Ergonomics Laboratory of the University of Sydney.

Towards Better Performance with Optimized Sport Equipment

Improving the performance in both top level and leisure time sports is one motivation for 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

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

One example of our work in this field in 2015 is the patented Tripstix design for highly functional, inflatable stand-up paddle boards. It uses a new dual chamber system technology called 'VacuuAir'. A vacuum chamber filled with granule encloses a high-pressure chamber, offering additional stability. This allows a board to be designed with the exact shape of a regular surfboard – including thin rails, a delicate nose, and a stable tail.

Brand New Award prize winning ceremony for TUM start-up Tripstix at ispo. Photo: A. Neumann

With its dual chamber system, the board is extremely stable and safe. It will keep afloat even when punctured.

Another optimization related to sports materials has been done on a racing bicycle frame. Its tubes are made of bamboo connected with carbon fiber composites. An extended test program was performed to improve its strength, stiffness and its fatigue behavior with the result of an optimized lay-up design.

Bamboo bicycle frame during fatigue tests

Understanding the Interaction between Athlete, Equipment and Environment

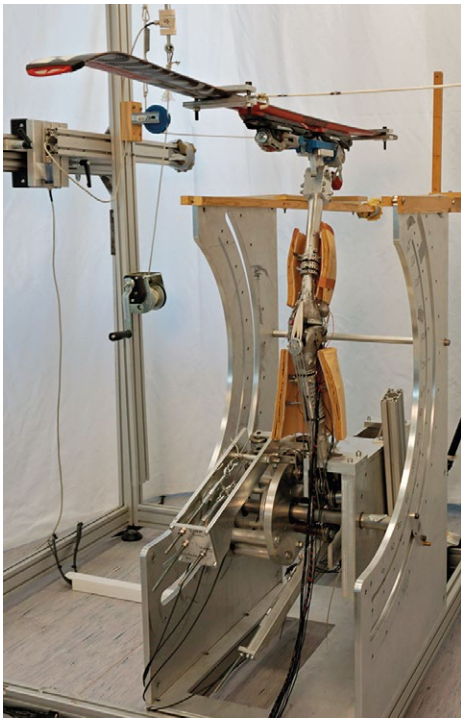
Instrumented skier with dynamometers, goniometer, differential GPS and inertia sensors

This important research field in sports engineering has also been part of our work in 2015. We continued a research project on behalf of endoGAP clinics which is motivated by the increasing number of total hip replacements in OECD countries. The majority of these patients regain full mobility and formerly active people like to go back into sports.
The aim of the project was a qualified estimation of hip joint loads in alpine skiing, confirmed by reliable field trial measurement data. The questions to be answered: Should their skiing continue to be allowed without reservation and which recommendations for limiting the acceptable skiing manoeuvres should be given?

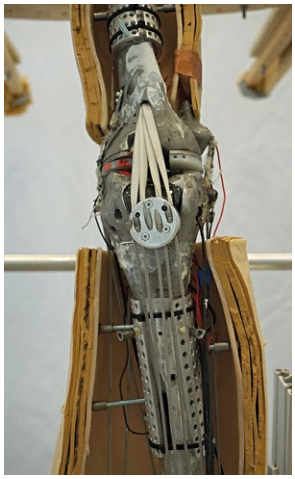
Attaching and wiring the inertia full body motion capture system

More Safety with Improved Protection Gear

Related 2015 Project
In alpine skiing knee injuries remain the major challenge for improved protection equipment. Systematic analysis of injury situations and human anatomy suggest that mechatronic ski bindings may provide the solution. Although patents for mechatronic ski binding concepts were submitted in the early eighties, no commercial product has appeared on the market.
The main reason is that the algorithm that controls such mechatronic bindings needs a comprehensive understanding of the complex interaction between the external loads and those of the different structures of the knee. An artificial lower leg including an instrumented knee has been realized and combined with a load simulation device. This allows systematic investigation of any combination of external forces and moments and measuring the resulting tension in the critical knee ligaments.



Artificial surrogate leg with load application unit for the development of mechatronic ski bindings and knee protectors



Knee with instrumented ligaments

Less Effort and More Fun Through Technical Support

Prototype 'QuadRad', a new category of electric driven lightweight vehicle, on the test bench

Electric bicycles are becoming more important as a mean of transportation. One of the biggest issues regarding electric bicycles is their inaccurate prediction of the residual range. For better prediction it is essential to gain detailed knowledge of the cyclists' fitness, the type of electric bicycle and the environmental resistances. In collaboration with TUM institute Automotive Technology (Professor Lienkamp) we have successfully implemented a control circuit that uses the rider's heart rate to manipulate the electric power support of this new type of lightweight vehicle, called 'QuadRad'.

Four-wheel electric bicycle 'QuadRad' with heart rate controlled support

Research Focus

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

Competence

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

Infrastructure

- Mobile skin- and core-temperature measurement
- Multi-body simulation software SIMPACK®
- Mobile EMG and spirometry
- Video-based motion analysis
- Leg surrogate with loading device
- Instrumented bicycle
- 5-axis fatigue testing device for bicycle frames

Courses

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

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Publications 2014-15

- Keshvari, B., & Senner, V. (2015). Comparison of Shoe-surface Tractions on Various Playing Surfaces in Futsal. Procedia Engineering, 112, pp. 267-272.
- Lehner, S., Frank, I. M., & Senner, V. (2014). Analyse typischer Verletzungsmuster beim Snowboarden unter Verwendung von MKS-, CAD- und FEM-Modellen: dvs Band 244. In A. Baca & M. Stöckl (Eds.), Sportinformatik X (dvs). Schriften der Deutschen Vereinigung für Sportwissenschaft, pp. 56-61. Hamburg: Feldhaus Verlag GmbH & Co. KG.
- Lehner, S., Huber, N., Baumeister, D., & Michel, F. (2015). Effektivität unterschiedlicher Stabilisierungssysteme des distalen Unterarms in Dorsalextension: Eine Untersuchung unter Verwendung von Computermodellen. Orthopädie Technik. Rehabilitation. Medizinprodukte, 66. Jahrgang (08), pp. 18-23.
- Lehner, S., & Senner, V. (2014). Impact Biomechanics – Use of Validated Models for the Evaluation of the Injury Risk. In Proceedings of the 3rd International Digital Human Modelling Symposium (DHM) 2014.
- Lehner, S., Geyer, T., Michel, F. I., Schmitt, K.-U., & Senner, V. (2014). Wrist Injuries in Snowboarding – Simulation of a Worst Case Scenario of Snowboard Falls. Procedia Engineering, 72, pp. 255-260.
- Meyer, D., Dungs, C., & Senner, V. (2015). Estimating the Relationship between Heart Rate and Power Output for Short Term Cycling Exercises. Procedia Engineering, 112, pp. 237-243.
- Meyer, D., Zhang, W., Tomizuka, M., & Senner, V. (2015). Heart Rate Regulation with Different Heart rate Reference Profiles for Electric Bicycle Riders. In T. Ahram, W. Karwowski, & D. Schmorrow (Eds.), Proceedings of the 6th International Conference on Applied Human Factors and Ergonomics (AHFE) 2015 and the Affiliated Conferences, Vol. 3, pp. 4213-4220. Elsevier.