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

Annual Report 2020

Jahresbericht 2020

Sport Equipment and Materials

Sustainable support for sport and health through technology

After several attempts to receive funding for our key topic 'knee injury prevention in alpine skiing' we have finally been successful: The Bavarian Research Foundation (BFS) supports a 3-year F&E-project together with five Bavarian companies and one Baden Württemberg company with a total budget of 920,000 euros. The target: Development of a world-wide unique prototype of a mechatronic ski binding. We are proud to belong to the ten funded projects of BFS in 2019.

More highlights from our 2019 activities:

- Launch of our new Master's module 'Sports Engineering' as core subject within the new M.Sc. study course Mechanical Engineering.
- Funding approval by Germany's Central Innovation Program for small and medium-sized enterprises ('ZIM') for collaborative R&D of a biopolymer hybrid turf for soccer fields.
- Funding approval by the International Graduate School Science and Engineering (IGSSE) for the project 'Initiative for a Translational Ethiopian-German Research Group to Achieve Transfemoral Exoprostheses' (INTEGRATE) together with TUM chair MedTech (Prof. Mala/Dr. Eblenkamp).
- Successful continuation of common R&D with global player PUMA on the field of fitness APPs' usability and UX.
- Extension of our collaboration with special interest magazine Outdoor Content Hub from Switzerland in the field of comparison tests for touring ski bindings and touring ski boots.

More Safety with Improved Protection Gear

Starting a Paradigm Change:
Towards Mechatronic Ski Bindings

In alpine skiing, the knee is the most injured body part – approximately 13,500 German skiers have suffered a knee injury during the 2016–2017 season. Besides the personal misfortune, considerable economic costs for surgery, rehabilitation, loss of working hours and secondary diseases are the result. Obviously, current ski bindings are not able to adequately prevent the leg from such overloads. Based on many years of former research, we have gained the firm conviction that we have to move away from the classical pure mechanical concepts and try to realize mechatronic ski binding concepts instead. At the end of July we received the funding approval (AZ-1375-19) of the Bavarian Research Council (BFS) for an ambitious collaborative research project. Its target: Develop such kind of a new binding together with a consortium of six companies. The innovative concept integrates different type of sensors into the ski, the binding, the boot and as well into the clothing. The sensors continuously measure the skier's velocity,

Handing over the funding approval to the consortium by Bavarian Research Council (Prof. Bode, sixth from left) and Dr. Jarothe (forth from right) representing the Bavarian State Ministry of Economic Affairs, Regional Development and Energy (TUM)

the knee angle, the loads acting to the foot and even the activity of major leg muscles. Based on this data, an algorithm will predict the injury probability in real-time. The binding reacts by adjusting the release level or – in case of acute risk – triggers the release of the ski boot.

Each of the six companies involved brings in essential expertise. Without this knowledge, this project could not be realized.

Field Study at Stilfser Joch/Italy setting up 16 cameras and performing the calibration of the observation space (Source: TUM-SpGM)

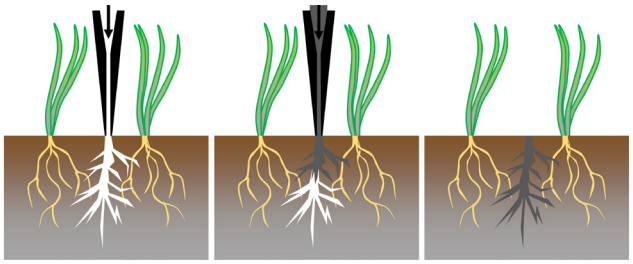
As the scientific contributor to this project, our part is to enhance our understanding of knee injuries, develop the algorithm to control the mechatronic binding and to provide necessary field data (see figures below). Moreover, we are in charge of the validation of the generated system versions. The project has a duration of three years.

Skier with skin-mounted markers for video-based 3D-motion analysis (Source TUM-SpGM)

Towards Better Performance with Optimized Sport Equipment

Compostable Hybrid Sports Turf with Optimal Biomechanical Load Profile

Hybrid turf – this buzzword has recently come up repeatedly in connection with stadium turf in the Bundesliga, the World Cup and the European Football Championship. Hybrid turf is the term used for natural grass sports surfaces that have been reinforced with artificial fibers to combine the playing characteristics of a natural grass with the robustness and resilience of an artificial grass: hybrid turf should be resilient and yet natural. The world's top football clubs already rely on the modern natural grass alternative. Eight of the ten stadiums are already equipped with the improved natural turf. The number of stadiums and training pitches with hybrid turf is continuously increasing.



From left to right: Generation of air pores in the soil, injection of liquid biopolymer, curing and stabilization of the biopolymer

Nevertheless, the hybrid turf available at present has several disadvantages. Depending on the system, between 10 and 100 tons of plastic are processed cost-intensively per football pitch. During conversion work, the

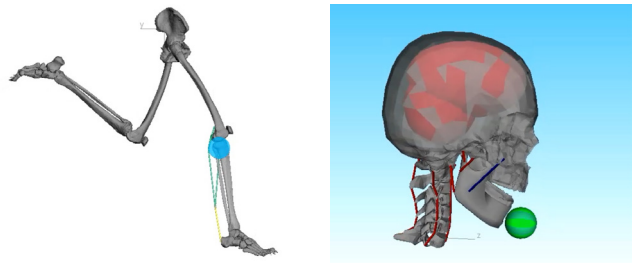
soil contaminated with plastic has to be disposed in an environmentally harmful manner. In addition, the proportion of non-contact injuries seems to increase. Footballers complain about the lack of elasticity and a too firm turf surface.
As part of a R&D started in October – funded by Germany's Central Innovation Program for small and medium-sized enterprises ('ZIM') – SpGM is contributing to the development of a new hybrid turf system. The project is a collaboration between our institute and the OEM EuroSportsTurf GmbH, the TUM professorship for Biopolymers in Straubing (Prof. Zollfrank) and two other industry and research partners. The project aims to develop a biopolymer that is injected into the existing sports turf surface using a new type of injection device. A root-like biopolymer mesh is intended to imitate the bionic effect of soil stabilization. Our part in this research is to take a close look at the interaction between the player and the turf in order to biomechanically optimize the new prototype. Field measurements and tests with our TUM TrackTester have been started. The results will serve as input for a multi-body simulation model of a soccer player.

Mechanical foot model of the TUM TrackTester to reproduce a realistic load pattern between shoe and turf

In order to also consider the deeper layers of the soil, we have started a cooperation with TUM Chair and Testing Institute of Soil Mechanics and Foundation Engineering, Rock Mechanics and Tunneling (Prof. Cudmani).

Understanding the Interaction between Athlete, Equipment and Environment

Redesign of our Teaching Module 'Digital Human Modeling'
Understanding the interaction between athlete equipment and environment is not only a topic for our research. It is also a major part of our teaching. Due to the embedding of our module 'Digital Human Modeling' in the new Master's course 'Medical Engineering and Assistance Systems', the module was completely redesigned. Starting this winter semester (2019–2020), a basic module will be offered every winter semester term and an advanced module in the summer semester. In terms of content, the focus will continue to be on biomechanical modeling using multi-body systems (MBS). Under intensive supervision, the students develop their own models for various biomechanical load cases, thus building up a basic understanding of the mechanics of human movements. Additionally, they learn where to find the needed biomechanical properties of modeled structures and which steps



Two multibody models developed by our students within the frame of the teaching module 'Digital Human Modeling'

are necessary to validate their mathematical model. At the end they possess reasonable knowledge on how to use basic elements of the rather sophisticated MBS-software package Simpack. This master module is also offered for students in the Master's course Human Factors Engineering (HFE).

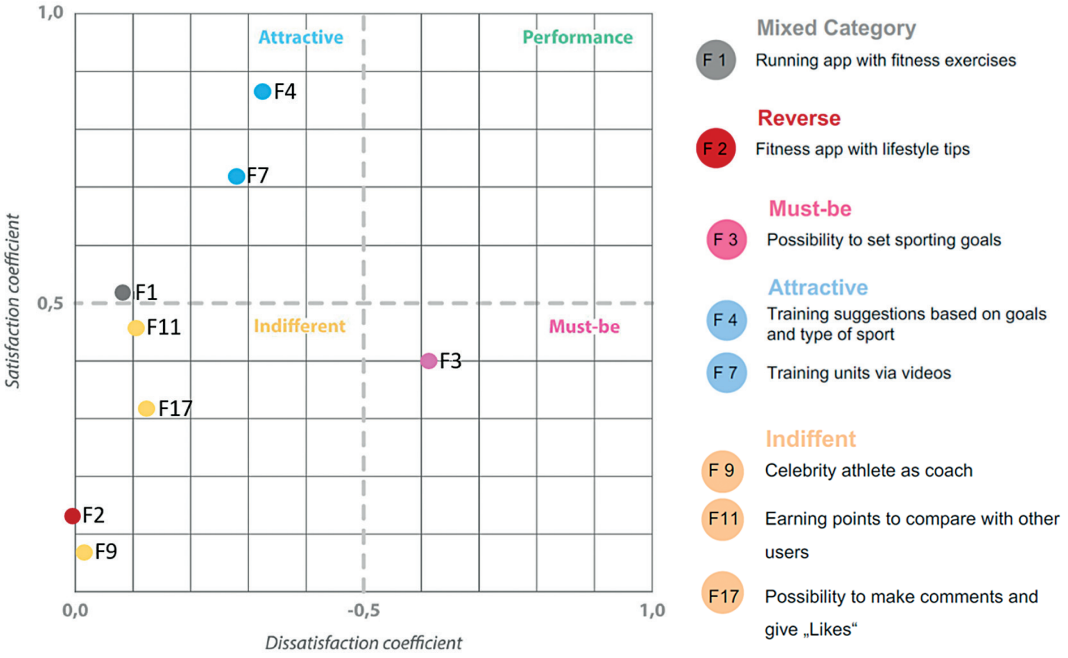
Health, Wellness and More Fun Through Technical Support

Fitness APPs under Critical Scientific Review

Sports and physical activity are often considered as the 'preventive medicine not taken'. This puts emphasis on the 'self-management of health' since people are individually responsible for their physical activity and well-being; however, often lack long-term motivation to exercise regularly. Mobile fitness applications (MFA) in sports and exercise show a huge potential to support people in attaining motivation. Despite a high willingness to use these kind of applications, the average period of use is comparably low, and manufactures have become aware of this problem.

A collaborative research project with the global player and sports manufacturer PUMA aimed at investigating this issue and evaluated the company MFA called 'PUMA TRAC'.

In the first step, we distinguished significant design variables for the app using a Kano Analysis (N = 117) and examining 25 possible features. Results revealed two 'attractive' features; however, merely one 'must-be' feature (see figure below). Hence, achievement related app functions (e.g., individual exercise plans or video demonstrations on workouts) tend to perform better than socially related functions, such as sharing workout information in social media. These results shed light on motivational variables. In the second step, we wanted to find out if a MFA which has been designed to specifically consider the users' individual implicit and explicit motive disposition would be able to affect their long-term usage behavior. Two versions of MFA were studied, the existing Puma Trac and a prototype fitness application which we have developed to better address the users' implicit achievement motives. The latter was quantified using two established measures, the Multi-Motive-Grid as semi projective measure using picture cues and the Unified Motive Scales. Regression analysis was performed to answer the question if the achievement motive is able to predict the continuity and length of usage of the app and if this relationship is stronger for our prototype version. The results revealed no relationship for the Puma Trac ($p = 0.204$) but a weak correlation for our prototype ($p = 0.057$). In conclusion, we consider this as a clear indication for possible contribution of such kind of mobile fitness apps. However they should further be improved by putting even more focus on achievement-related incentives. We further hypothesize that these findings may also be transferred to other motive dispositions, providing affiliation- and power-related incentives for users with high disposition on these motives.



Kano-Analysis of MFA 'Puma Trac' on 'must-be', 'performance', 'indifferent', and 'attractive'-features

Sport Equipment and Materials

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Research Focus
- Function & functionality of sporting goods
- Safety & protection gear to avoid injuries
- Thermo-physiology in sport garment design
- Footwear – sport surface interaction

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®
- Portable EMG and spirometry
- Video-based motion analysis (Simi Motion)
- Leg surrogate with loading device
- Instrumented bicycle
- 5-axis fatigue testing device for bicycle frames
- Ski boot 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
- Methods in Sports Engineering
- Field Studies Sport Technology
- Interdisciplinary Research Project

Publications 2019

- Kopp, P. M., Senner, V., & Gröpel, P. Regular Exercise Participation and Volitional Competencies. Sport, Exercise, and Performance Psychology. Advance online publication. https://doi.org/10.1037/spy0000197
- Passler, S., Bohrer, J., Blöchinger, L., & Senner, V. Validity of Wrist-Worn Activity Trackers for Estimating VO2max and Energy Expenditure. International Journal of Environmental Research and Public Health, 16 (17). https://doi.org/10.3390/ijerph16173037
- Passler, S., Müller, N., & Senner, V. In-Ear Pulse Rate Measurement: A Valid Alternative to Heart Rate Derived from Electrocardiography? Sensors (Basel, Switzerland), 19 (17). https://doi.org/10.3390/s19173641
- Senner, V., Lehner, S., Michel, F. I., & Brügger, O. Modelling and Simulation to Prevent Overloads in Snowboarding. In A. Baca & J. Perl (Eds.), Modelling and simulation in sport and exercise (pp. 211–236). London and New York: Routledge / Taylor & Francis Group
- Vogel, P., Spitzenpfeil, P., Frühschütz, H., Senner, V., & Goll, M. Simulation des Schwingungsverhaltens des paralympischen Sportgeräts Monoski – Systematische Parametervariation in einem Mehrkörpermodell. In Dekan der Sportwissenschaftlichen Fakultät der Universität Leipzig (Ed.), Schwerpunktthemen: Olympische Winterspiele; Beiträge der Preisträger des dies academicus 2018 (LIX (2018) Heft 2, pp. 149–160). Berlin: Lehmanns Media Verlag