Simulation and Optimization of Race-Bike Training on Real Tracks

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Computer science in sports is an emerging interdisciplinary field which has evolved in the last 20 to 30 years. Recording devices for a host of physical and physiological parameters have become available to the professional athlete as well as to hobby and amateur sportsmen. These are used for monitoring and measuring sports activities both in the lab and in the field. However, these commercial devices come with specific software that does not readily support a joint representation and analysis of the data which is desirable for scientific research.

In the scope of the Powerbike project of the work group Multimedia Signal Processing, we strive to record, fuse, and synchronize all types of performance data and develop methods for modeling, analysis, and visualization. We concentrate on endurance sports with emphasis on competitive cycling since this kind of data involves long time-series that are more homogeneous and less prone to random events as e.g. game sports. The goal of our work is to provide a simulator system that enables racebikers to improve their performance in training and in competition.

Measurements from a palette of devices, including common bike computers, GPS-recorders, power meters, and spiroergometers are combined requiring data fusion and synchronization. In addition, we consider the integration of maps with elevation information together with recorded video footage of training courses. We also apply biofeedback methods that require complex data processing and real-time visualization.

For the simultaneous visualization of large information quantities we use the Powerwall at the University of Konstanz (4640 x 1920 pixels), which offers the display of high resolution terrain data and maps together with static and dynamic parameter sequences from measured training rides or a running biofeedback simulation.

The bicycle simulator is based on a Cyclus 2 ergometer and a custom PC-based platform independent control software. Currently, the main components of the simulation are

- a computer controlled pedal resistance according to the height profile of a cycling track, measured by GPS,
- simulation of arbitrary gear shifts,
- acquisition and visualization of time, distance, speed, cadence, heart rate, gradient profile, power and gear, and
- a synchronized video display of the cycling track that shows the current position.

This thesis particularly focuses on the design, integration, and validation of an appropriate mathematical performance model that accounts for the physical properties of the track and the environment in conjunction with the human performance potential. This model shall be used to optimize the cyclists behavior on real tracks. Although many approaches for systematic planning of physical strain exist, nowadays training and contest scheduling is still subject to creativity and experience. The athlete's individuality and the specific characteristics of the track are not taken into account appropriately and most training principles cannot be generalized because they solely rely on empiric foundations.

On the one hand existing models of cycling predict the velocity of a biker given the human input power. In essence, they account for the downhill slope force, wind and rolling resistance, wheel bearing friction and inertia. On the other hand there are various concepts of modeling human performance capabilities. The most famous rely on the parameters critical power (which is the largest constant power a human can perform for a long time) and anaerobic work capacity (which is a fixed budget of energy a body can call only once for a short high-power activity). Refinements of this model comprise more complex biological processes in the human body. Furthermore, there are performance models that incorporate online measurements like the heart rate to improve the accuracy of prediction during an activity.

For our purposes, we require a combination of these two model classes that copes with their dynamic interplay. The new model shall be specialized on bicycle training and exploit the outstanding measurement opportunities of our laboratory environment that is not achievable in the field. Furthermore, we need an optimization algorithm that efficiently exploits the human power capabilities to complete the course in minimal time. Eventually the system needs extensive validation of its accuracy and an evaluation with respect to the benefit for sports science.

The project is interdisciplinary and external expertise from sport science, and sports medicine as well as from other areas of computer science are required. Dr. Dietmar Lüchtenberg of the Deptartment of Sport Science at the University of Konstanz, oversees and guides the studies from the training science point of view. Dr. Björn Stapelfeld as chair of the Radlabor GmbH in Freiburg, supports the project with his research experience in cycling and measurement devices. Finally Dr. Peter Bak, postdoc in our DFG Graduate School, will help to design and evaluate the human computer interfaces in the biofeedback part of the project.