Related projects

- BrainCycles - Differentiation of oscillatory brain networks subserving bicycling and walking movements in Parkinson's disease
- Analysis of chaos in indoor pedaling motion

Invitation

Bachelor and master students are welcome to do projects and theses with us. We are also looking for riders to participate in empirical studies and for student assistants to work in our group in the research project Powerbike. The focus is on the further development of our bicycle simulator. Currently, possible tasks include:

- Enhancement of the GUI in particular to exploit touch-screen technology
- Integration of additional sensor signals such as heart rate, cadence, and pedalling power via the ANT protocol and TCP-IP
- Integration of height profiles measured using a differential GPS and inertial navigation system
- Improvement of the synchronization of video with the cycling speed

Selected publications

Dahmen, T. Optimization of pacing strategies for cycling time trials using a smooth 6-parameter endurance model. Proc. IACSS. (2012).

Dahmen, T. and Saupe, D. and Wolf, S. Applications of mathematical models of road cycling. Proc. MATHMOD 7. (2012).

Dahmen, T. Computing a field of optimal pacing strategies for cycling time trials. Proc. Sportinformatik. (2012).

Dahmen, T., Byshko, R., Saupe, D., Röder, M., Mantler, S. Validation of a model and a simulator for road cycling on real tracks. Sports Engineering. 14 (2-4), 95–110. (2011).

Dahmen, T. and Saupe, D. Calibration of a power-velocity-model for road cycling using real power and height data. IJCSS. 10, 18–36. (2011).

Wolf, S. and Dahmen, T. Optimierung der Geschwindigkeitssteuerung bei Zeitfahrten im Radsport. Proc. Sportinformatik. 235–239. (2010).

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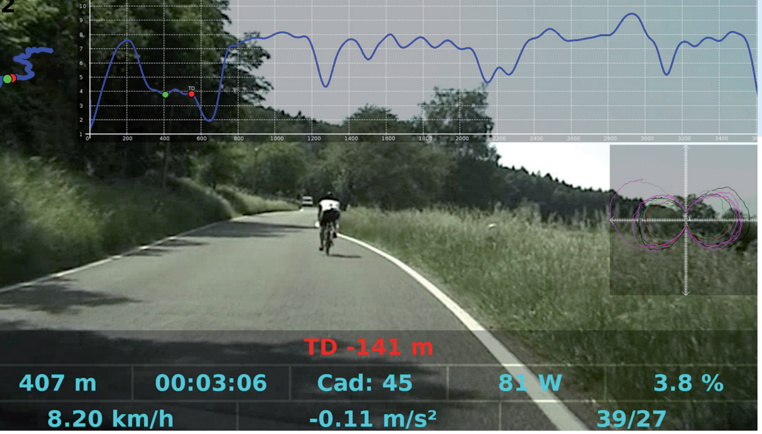
Department of Computer and Information Science
Work group Prof. Dr. Dietmar Saupe

The Powerbike Project

Universität Konstanz



We develop methods for data acquisition, analysis, modeling, optimization and visualization of performance parameters in endurance sports with emphasis on competitive cycling.

Measurements from a palette of devices, including common bike computers, GPS recorders, and power meters, are combined requiring data fusion and synchronization.

A part of the project is a bicycle simulator based on a commercial ergometer and our own PC-based control software. The main components of the simulation are:

- computer controlled pedal resistance according to the height profile of a cycling track
- the recording and visualization of training data measurements (speed, cadence, power, heart rate, height profile etc.)
- video display of the cycling track at the current position.

Our system contains three layers. In the parameter layer the following signals are recorded to develop and test the models: speed, cadence, heart rate, power, gear ratio, GPS coordinates, video, VO2, lactate levels.

Given the necessary parameters, the simulator is able to produce a brake force that comprises forces due to a gradient, air resistance, friction and acceleration. The bicycle simulator allows realistic training in a laboratory environment.

The model layer consists of physical models of the track and its environment and physiological models of human performance. These models are used to predict the total riding time for given pacing strategy, to fill in missing data, to estimate power from other variables, and to fit model parameters to data measurements.

In the computational layer optimal control algorithms are used to compute pacing strategies that minimize time to arrival or exhaustion for given total race.

$$\underbrace{mg\frac{dh}{dx}}_{F_{\text{pot}}}+\underbrace{\frac{1}{2}c_d\rho A\dot{x}^2}_{F_{\text{air}}}+\underbrace{\mu mg}_{F_{\text{roll}}}+\underbrace{(\beta_0+\beta_1\dot{x})}_{F_{\text{bear}}}+\underbrace{\left(m+\frac{I_w}{r_w^2}\right)\ddot{x}}_{F_{\text{kin}}}=\frac{\eta}{\gamma}\frac{l_c}{r_w}F_{\text{ped}}$$

Why road cycling?

In comparison with other endurance sports road cycling in particular offers more opportunities for research:

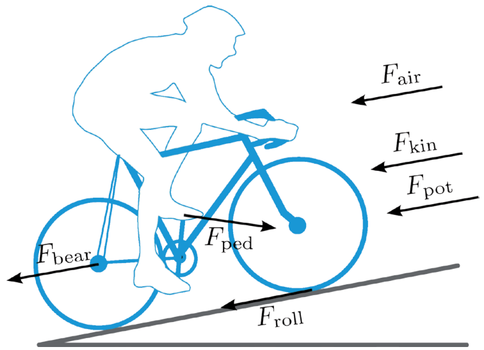
- Mechanical model of cycling available
- For endurance sports, physiological models may be feasible and useful
- Lab and field studies possible
- Sensors integrate unobtrusively
- Performance measurement (power) readily available
- Popular sport: healthy, fun ;-)

Equipment

We use a differential GPS device to extract high-precision trajectories of real cycling tracks. In track sections, where the differential GPS quality is degraded due to obstacles along the track, we measure cycling speed and power using a power meter in conjunction with a commercial GPS device to estimate the gradient and thus enhance the differential GPS measurements.

Mechanical model

The equilibrium of the pedaling force F_{ped} and resistance forces defines the relation between pedaling power P_{ped} and cycling speed. The resistance forces are composed of the gravitational force F_{grad}, aerial drag F_{air}, frictional losses in the wheel bearings F_{bear}, rolling resistance F_{roll}, and (optionally) the slipstream force F_{slip}.



The equilibrium of forces is given by a differential equation with the parameters in the table which must be measured or taken from the literature.

Cyclist and bicycle	
total mass (cyclist, bike)	m
wheel circumference	c_w
wheel radius	r_w
wheel inertia	I_w
cross-sectional area	A
length of crank	l_c
bearing coefficient	β_0
bearing coefficient	β_1
mechanical gear ratio, bicycle	γ

Course and environment	
friction factor	μ
gravity factor	g
drag coefficient	c_d
air density	ρ
length	L
height	$h(x)$
chain efficiency	η

Physiological model

We use a system of first order differential equations with parameters: exertion, aerobic capacity, anaerobic capacity and critical power (CP). The CP model can be conceptualized as a hydraulic model with two vessels containing fluids representing metabolic energy. One vessel of infinite capacity represents the aerobic energy supply. The other one is the anaerobic energy supply with limited capacity. The vessels are interconnected by a tube of fixed diameter, which allows the flow of the fluid from the aerobic to the anaerobic vessel. The flow is limited by the critical power.

During exercise, the flow of the fluid in the system represents the breakdown of high energy phosphates and oxygen consumption. During recovery, the anaerobic vessel is refilled from the aerobic vessel modelling the repayment of the oxygen debt. The net power output of the body is represented by the fluid flow out of the anaerobic vessel.