TRAINING- AND CONTEST-SCHEDULING IN ENDURANCE SPORTS BY MEANS OF COURSE PROFILES AND PERPOT-BASED ANALYSIS

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Introduction

Scheduling of training and contests in outdoor endurance sports – e.g. running, biking, or skiing – is difficult through course contexts (ground condition, slopes etc) and delayed psychological reaction on load changes (see Figure 1).

Figure 1: Load-performance-interaction depending on physiologic delays and course context

In the following, some of those impacts are exemplarily discussed for the case of running: Figure 2 shows the effect of delayed reaction on periodically changed speed on plain ground: From bottom to top, the first line contains the speed values (6.5 and 8.0 km/h), which are graphically reproduced as profile, followed by the corresponding heart rate profile and the heart rate maximum values in the top line.

Figure 2: Delayed influence of strain and recovery in case of speed changes (also see explanations in the text)
The marked delay intervals exemplarily indicate the time needed until stabilizing after a speed change. The figure shows the standard case that the recovery delay is larger than the load delay. Figure 3 demonstrates, for the example of a periodic height profile (graphic on bottom), that the slope-caused load can affect the heart rate profile (graphic in the middle) more than the speed-cause load does (graphic on top). The red arrows mark phases of inverse profiles, while the green arrows mark phases of equal tendencies.

All examples are calculated on the basis of original data using the PerPot-derivate "SpeEdi Run".

**Figure 3**: Heart rate profile caused by speed changes only (graphic above) compared to a profile that additionally is influenced by slope changes (graphic below) (also see explanations in the text)

The aim of the paper is to demonstrate how a model-based analysis can help for predicting performance profiles in context-depending load situations and supporting load scheduling in contests.

**Methods**

Load-performance-interaction can be analyzed by means of the tool "SpeEdi Run" that was derived from PerPot (see Perl, 2005), where speed is taken as load input and heart rate is taken as performance output. Additional impact parameters are taken from the course profile, in particular from the positive and negative slopes:

Depending on the original speed $v_0$ and the original slope $S$, a transformation $v_R = \lambda(S,v_0) \times v_0$ calculates a (virtual) reference speed $v_R$ that represents the load effect regarding the resulting heart rate output. Each $v_0$ defines a characteristic $\lambda$-function, which looks like a piece of a parabola, and the values of which have to be taken from experiments (see Figure 4, right graphic).
To this aim the course is recorded and measured by means of GPS and altimetry and then departed into segments of (more or less) constant slope. For each segment the $\lambda$-transformation can be done in the way described above. Figure 4 in the left graphic shows how the GPS position data $P$ and the altitude data $H$ are used to calculate the slope $S$, while the right graphic shows how $S$ and $v_0$ define $\lambda(S,v_0)$ which then is used to calculate $v_R$ (see Endler, 2006).

After calibrating the $\lambda$-transformation to the athlete, the course-specific load profile can be scheduled and optimized.

Finally it has to be taken into consideration that (besides others) age and fitness have impacts on the delay values that in turn characterize the heart rate reaction on speed input. For example, the recovery delay $DR$ will increase by fatigue, which depends on age and fitness as well as on the time already used on the run. As is shown in Figure 5, age, fitness, and the time used characterize a fatigue $\Delta DR$, which modifies the prototypic value $DR$ to the personal situation-specific value $DR^* = DR + \Delta DR$.

Figure 5: Fatigue depending on age, fitness, and the time used and its impact on the recovery delay $DR$ (also see explanations in the text)

**Results**

Figure 6 demonstrates the output of a SpeEdi Run analysis: The lower graphic shows the altitude profile with segments and corresponding slope values. The table between the graphics shows the original speed values and the reference speed values of each segment. The upper graphic shows the heart rate profile and corresponding segment maxima, which are calculated from the reference speeds by means of SpeEdi Run.

In the same way, the optimal speed profile can be calculated given a heart rate profile as objective function, which can help for improving the runner's performance and saving his health. In Figure 6 the objective heart rate profile was defined by "$\leq 150"$. The red line shows the optimized speed pro-
file, where the lowest speeds – as expected – are calculated for the two segments of largest positive slopes, while the highest speed is found only for one of the segments with the largest negative slope. The reason is that an increase of the speed in the fourth segment would cause a delayed increase of the heart rate in the sixth segment to "151".

Figure 6: Speed profile optimized under the objection of not to exceed a heart rate of 150 (also see explanations in the text)

In turn, the correspondence between speed and heart rate can be used for controlling the run just watching the heart rate – i.e. optimizing the speed by matching the intended heart rate. This approach exemplarily was got to work successfully in a test, where one of the authors (Stefan Endler) in his first hill marathon missed the scheduled time of 3:00 hours by only 10 minutes or 5.6% – using a heart rate meter as only control instrument.

References