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Planning the sports training sessions with the bat algorithm

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ABSTRACT

Planning proper sports training has always been a very challenging task for coaches. In line with this, they need to have almost two special abilities: firstly, to have a lot of earlier experiences with sports training and secondly, to know the capability of their athletes very well. New ways in planning sports training have emerged with development of pervasive and mobile technologies. Recently, a GPS receiver is one of the most useful parts of each standard sports watch that enables athletes to track the duration of their sports activities and analyze them later on digital computers using GPS viewers. Most sport's watches are also capable of measuring an athlete's heart rate during activities. Both measures represent reliable data sources that can be used for planning the sports trainings by coaches. In this paper, we introduce a novel intelligent planning method for sports training sessions, where the training plans are generated on digital computers using the bat algorithm according to reliable data obtained from sports watches. Real-world experiments showed promising results that encouraged us to proceed with this research also in the future.

1. Introduction

Athletes today are having a lot of possibilities to improve their training performance and therefore can be better prepared for competitions. Nowadays, a big part of the sports life of every athlete is connected with training technologies [1]. These technologies are composed of:

- smart sport watches,
- power and cadence meters,
- different variants of heart rate monitors,
- different variants of music players,
- and many more.

Sport watches probably represent the most important pieces of these technologies. The first interest in sport watches arose in the middle of the 90s when the Finnish company Polar released very powerful sport watches with heart rate monitor and timer for measuring the duration of sport activities. These watches have the following functions:

- monitoring the total duration of a sports activity,
- watching current and maximum heart rates,
- monitoring current elevation and total ascent,
- current temperature,
- saving activities on sport watch.

Additionally, cyclists have also obtained some sensors which were put on the bikes and are capable of monitoring the speed. Furthermore, later variants of these watches provided connection with digital computers and in line with this, an online analysis of workouts.

These sports watches had been one of the more important training tools for every amateur and professional athlete in the past. Then, the training technology made a big step forward. An expansion of the GPS technology allowed many companies to develop sports watches with GPS receivers [2]. These watches have huge advantages over previous generations of watches, because they measure very precisely the characteristics data about trainings when athletes using the GPS receiver. As a result, runners and bicyclists do not need to use any special sensors for determining their speed, altitude and duration of activities. Currently, companies like Garmin, Polar and Suunto are making serious efforts to develop additional options for such watches in order to meet the needs of athletes worldwide.

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Certainly, connection with digital computers and online analysis of trainings are the greatest advance of these sport watches. For instance, Garmin Connect web service developed a majestic online training service, where users can analyze their workouts after their performed activities. The web service also encourages athletes to practice more in order to reach better results on the official competitions. On the other hand, the results of these workouts can also be exported into a digital computer in XML form and analyzed later.

An aim of this paper is to propose an intelligent planning for sports training using a digital computer on the basis of reliable data exported from sports watches in the form of XML activity files [3]. Essentially, two measures are important for this planning: a duration of activity and an average heart rate. Both measures are precisely measured using the sports watches which saves data about specific activities in their internal memory and can be exported onto a digital computer for the further analyses. On the basis of these exported data, the plan of sports training for specific athlete is performed using a bat algorithm.

The bat algorithm belongs to a class of Swarm Intelligence (SI) [4–6]. This algorithm arose in the year 2010, when Yang [7] created a new optimization algorithm inspired by the behavior of microbats that use a special mechanism called echolocation. Echolocation is used by bats for orientation and prey finding. The original bat algorithm was applied to various benchmark functions, where have achieved solid results. The convergence rate of this algorithm was improved in the study [8], where the authors hybridized the original bat algorithm with differential evolution strategies (HBA). In the study [9] the same authors dealt with hybridizing the bat algorithm using differential evolution strategies [11] and a random forests machine learning method (HBARF). The complete survey regarding bat algorithm can be found in [12].

The proposed algorithm for planning the sports training sessions is able to create the training plan for a given training period of a specific athlete. It starts with a set of base trainings characterized by different durations and average intensities determined by the average heart rate. The base training sessions are selected by the coaches on the basis of XML activity files obtained in the past. Thus, it is assumed that the long-duration training sessions are more suitable for the starting periods of training, while the more intensive short-duration training sessions need to be performed during the more matured period of training, when the athlete is already fit. Indeed, the number of fully intensive training sessions is kept to a minimum.

Although there are a lot of different commercial tools for tracking sports activities, as we know there is no system for the intelligent planning of sports training on a digital computer. Our proposed algorithm is therefore mainly devoted to coaches as a help tools for planning the optimal training period for the specific athlete preparing himself/herself for upcoming competitions. The results of this algorithm conform with the expectations of professional coaches and therefore open-up a lot of potentials for the further development.

The structure of this paper is as follows. Section 2 introduces the basics of a sport training. Here, the mathematical model is developed for planing the sports training. In Section 3, the bat algorithm for planning the sports training sessions is discussed in detail. Experiments and results are the subject of Section 4. Section 5 provides a conclusion, where our work is summarized and the directions for the further developments are outlined.

2. Sports training

According to the definition the sports training is a process built on scientific and pedagogical principles, which affects the performance of an athlete using planned and systematic training sessions, thus allowing him/her to strive for the highest achievements [13]. The ultimate effect of the supplied process of sports training can be seen in an athlete's improved form, the increased capacity of his/her body or/and in the worst case, over-training. In relation to the expected competitive performance, the sport form can be described as a phenomenon of short-term increased capacity by the athlete. An athlete's achieved sport form in an expected competition means that his process of sport training was the most effective. The efficient process of sports training is also described as a qualitative approach that optimizes an athlete's time dedicated to training. Namely, the frequency of sports exercise is always in conflict with its intensity. In other words, a large amounts of time spent exercising could not be carried out very intensively.

Most athletes use heart rate monitors for measuring the sports training intensity. The time duration (TD) measured by a stopwatch and the intensity of the workout measured by a heart rate monitor (HR) are the simple metrics for monitoring the difficulty of sport training. Banister [14] has made step forward towards smart training analysis during training sessions using the method “TRAining IMpulse” (TRIMP) for quantifying the training load. Nowadays, power meters are more often used by bicyclists for evaluating the difficulty of sport training intensity instead of the physiological parameter HR. In line with this, Friel [10] for this purpose proposed a measure Training Stress Score (TSS) as a way of expressing the difficulty from a training session regarding workload. The measure can be expressed as a product of the intensity and duration necessary to accomplish the workout.

2.1. Mathematical definition of the problem

The problem of planning the sports training can be mathematically defined as follows. Let us assume a set of base training sessions $T=\{t_1,\ldots,t_n\}$ characteristics for certain athlete. Each base training session is specified by the athlete's average heart rate $\overline{HR}_i$ and the time duration TD_i, which determine the profit rate as $p_i=c_i\cdot\overline{HR}_i/TD_i$, where $c_i=\overline{HR}_i/\overline{HR}$ and $\overline{HR}=1/n\cdot\sum_{j=1}^{n}\overline{HR}_j$. Here, a coefficient c_i is used to normalize the values of $\overline{HR}_i$. The $\overline{HR}_i$ is measured by minutes (min), while the TD_i by beats per minutes (BpM), counting the number of heart beats per minutes. The task of the optimal planning the sports training is to find the integer vector $\mathbf{y}=\{y_1,\ldots,y_n\}$ determining the training plan such that the error rate (er) is minimized, in other words

$$er^*=\min|K-hr|, \tag{1}$$

where K the intensity factor that prescribed the maximal heart rate reached during the training period, and hr is defined as follows:

$$hr=\frac{1}{n}\sum_{i=1}^{n}\overline{HR}_i\cdot y_i\le K,\quad y_i\in[1,n]. \tag{2}$$

Note that hr denotes the calculated heart rate hr obtained by a specific training plan $\mathbf{y}$. In practice, coaches would like that the calculated heart rate hr is as close to the prescribed intensity factor K as possible. As a result, when the ideal solution is found the calculated heart rate hr matches value of the intensity factor. In that case, the error rate hr must be zero.

Additionally, a training effort value ev is calculated for each training plan that estimates an average effort needed by an athlete to finish it. The training effort value is expressed as

$$ev=\max\sum_{i=1}^{n}p_i\cdot y_i. \tag{3}$$

The vector $\mathbf{y}$ in Eq. (3) counts the number of the same training sessions y_i, where the efficiency of i-th training session depends