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Editorial

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Dear readers:

Welcome to the summer 2011 issue of the **International Journal of Computer Science in Sport (IJCSS).**

Two research papers, two scientific reports and three project reports have been included within this issue.

The study by **Nico Ganter, Kerstin Witte** and **Jürgen Edelmann-Nusser** evaluates training and performance development techniques based on dynamical systems theory for the sport cycling.

Keith Lyons discusses sport coaches' use of cloud computing, illustrating current trends and approaches including various applications by the example of canoeing in Australia as well as risk factors.

Hristo Novatchkov, Sebastian Bichler, Martin Tampier and **Philipp Kornfeind** demonstrate real-time training and coaching methods integratin ubiquitous technologies by presenting current developments of a mobile coaching framework.

The paper by **Kerstin Witte & Peter Emmermacher** presents an equipment comprising a software tool and video database for assessment of visual perception and anticipation ability in combat sport.

The investigations made by **Andreas Fischer, Martin Do, Thorsten Stein, Tamim Asfour, Rüdiger Dillmann** and **Hermann Schwameder** compare the use of Artificial Neural Networks (ANN) and Support Vector Machines (SVM) regarding the identification of subjects on the basis of kinematic walking and running data.

Armin Kibele reports on the implementation and evaluation of an eLearning tool for academic teaching providing biomechanical analysis of motor performance in sports.

Lastly, **Michael Stöckl** and **Martin Lames** demonstrate a visualization method for mapping affordances and constraints influencing the field's play in golf.

If you have any questions, comments, suggestions and points of criticism, please send them to me.

Enjoy the summer!

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The Development of Cycling Performance during the Training Program: An Analysis using Dynamical Systems Theory

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Abstract

There is common agreement that an appropriate framework for training and adaptation needs to consider the complexity and non-linearity of athletic performance and its response to training. General concepts like dynamical systems theory (DST) deal with such characteristics under the idea of self-organizing systems but still lack of empirical verification in the field of training and adaptation. In this paper, first, a DST approach to training is detailed. Second, on the basis of empirical data of cycling training, it is evaluated whether training process related data support the proposed DST approach. Therefore, training and performance development of ten cyclists (recreational to competitive level) were monitored during a ten-week cycling training program. Additionally, changes occurring at the microscopic level in the neuromuscular system were analyzed by means of surface electromyography (EMG). The results underpin the non-linear and time-delayed relation of training and performance. Further, the performance development observed during the training program can be characterized by stable patterns in the performance dynamics, described as performance states and transitions between these states, promoting the concept of self-organizing states observable at the macroscopic level.

KEYWORDS: DYNAMICAL SYSTEMS THEORY, TRAINING PROGRAM, CYCLING, SYNERGETICS, ELECTROMYOGRAPHY

Introduction

In order to improve performance in competition, athletes must prepare themselves through a training process (Smith, 2003). From a global perspective, the training process involves the physical, technical, intellectual and psychological preparation of an athlete through physical and mental training (Harre, 1982). For the sports coach a thorough understanding of the relationship between training and performance is essential in order to organize the athlete's training program (Jobson et al., 2009). However, the performance response to training is known to be highly individualized (Mujika et al., 1996; Hellard et al., 2002; Avalos et al., 2003; Hellard et al., 2006; Borresen & Lambert, 2009). In order to further the understanding of the individual training-performance-relationship, a growing interest in the application of systems theory for the training analysis exists (Busso & Thomas, 2006).

The systems theory attempts to abstract a dynamic process into a mathematical model, in which at least one input and one output are related by a transfer function (Busso & Thomas, 2006). With respect to the training process, the athlete is considered a system, in which the input (training) leads to an adequate output (performance). A modeling approach, based on systems theory, was first proposed by Banister and co-workers (Banister & Calvert, 1975; Calvert et al., 1976). Further refinements and modifications of the original model have led to a broad application of this approach for training analysis in several kinds of sports (review in Taha & Thomas, 2003). However, the empirical evaluations of the model indicated high variability in the modeled performance response to training (Mujika et al., 1996; Hellard et al., 2006; Taha & Thomas, 2003; Pfeiffer, 2008). Besides the simplification and some methodological limitations inherent to the used systems approach, possible reasons for the inconsistent findings can be seen in the fact, that the Banister model is based on a linear mathematical concept, but adaptation in the athlete is a non-linear phenomenon.

The common agreement on the complex nature of sport performance related phenomena is in contrast to the classical analytic reductionism approach utilized when analyzing athletes and training processes. By simply understanding the body as a machine divided into parts and the performance as the simple sum of different qualities, research based on this approach often offers poor explanations of athletic performance and may increase the distance between theory and practice that characterizes training science (Balague & Torrents, 2005). Consequently, alternative concepts, based on a complex understanding of performance need to be considered. The dynamical systems theory (DST) has developed in diverse sciences and was applied to the study of movement coordination (important first works by Kelso and co-workers; e.g. Kelso, 1995). It has emerged as a viable framework for modeling athletic performance with respect to processes of coordination and control in human movement systems, in which movement patterns emerge through processes of self-organization (Davids et al., 2003). By dealing with complexity and non-linearity, DST offers potential for the explanation of common phenomena in training and adaptation like individuality and non-repeatability of performance responses or sensitivity to small fluctuations that cannot be explained by classical concepts.

The understanding of the training process and the biological adaptation as a complex and non-linear dynamical system has led to a paradigm shift in the analysis of training responses from linear concepts to individual non-linear process-oriented concepts (Hohmann et al., 2000; Perl, 2001; Edelmann-Nusser et al., 2002; Hellard et al., 2002; Avalos et al., 2003; Balague & Torrents, 2005; Hellard et al., 2005; Pakenas et al., 2007; Pfeiffer, 2008; Jobson et al., 2009). Hohmann et al. (2000; 2002) suggested applying a synergetic concept of training, in which the training process and the resulting adaptation in the athlete is better understood as a complex dynamic system. Based on such understanding, alternative and non-linear concepts like neural networks (Hohmann et al., 2000; Edelmann-Nusser et al., 2002), the Performance-Potential metamodel “PerPot” (Perl, 2004) and non-linear extensions of the Banister model (Busso et al., 1997; Busso, 2003; Hellard et al., 2005) have been applied and revealed promising results for systems modeling of the training-performance-relationship.

In the following, a dynamical systems theory (DST) approach to training based on the synergetic concept of training proposed by Hohmann et al. (2000; 2002) and the synergetic concept of movement coordination from Witte et al. (2003) shall be formulated.

A Dynamical Systems Theory (DST) Approach to Training

The DST approach utilizes the synergetic concept (see Figure 1), a theory of self-organization and pattern formation in complex systems (Haken, 1983). In the synergetic concept, complex systems consist of several interacting subsystems which themselves may be composed of other subsystems. One or more control parameters externally or internally influence the systems behavior. A system may become unstable and adopt a new macroscopic state, when control parameters reach a critical level. The few collective variables that macroscopically characterize the ordered state of the system are called the "order parameters". According to the slaving principle, the order parameters govern ("enslave") the behavior of the subsystems, which in turn, through their interaction, generate the order parameter. Stable patterns in the dynamics of the order parameters are called attractors and the change between two attractors is known as a phase transition (Haken, 1983).

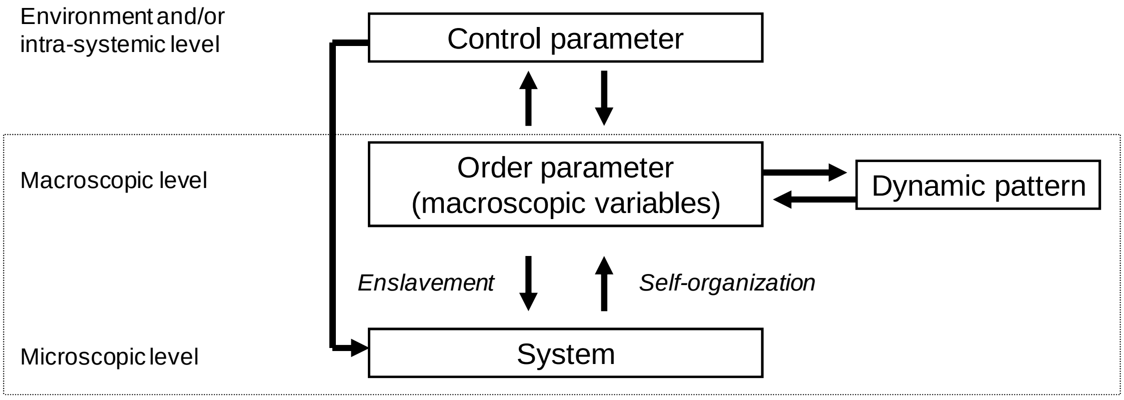

Figure 1. Basic synergetic concept (modified from Schiepek & Strunk, 1994).

The DST approach to training is illustrated in Figure 2. At the macroscopic level, it is assumed that the athletic performance ability represents the order parameter of the system. The training load is considered the control parameter of the system: During planning the training objectives are established and the training program is designed, that is, type, volume, intensity and frequency of training sessions are arranged in order to achieve the objectives. In the process-oriented model, the control parameter training load comprises the volume and intensity of training, and the frequency is represented in the time history of training load. At the microscopic level, the training load (i.e. volume and intensity) of each training session is known to induce stress in various functional subsystems as the basis for adaptations to occur (e.g. Keul et al., 1996; Hawley & Stepto, 2001). The complex interaction of the functional subsystems at the microscopic level leads to a self-organization of the system, detectable at the macroscopic level, through stable patterns in the dynamics of the order parameter, which in turn enslaves the subsystems' behavior. Since each training session leads to an adaptive response of the organism and consequently changes the system itself, the same training load applied at a later time will produce a different response. In abstract terms, the change of the order parameter over time (dx/dt) is given as a nonlinear function $F_\lambda(x(t))$, with λ standing for a control parameter, depending on the current training load, the former training chronology and the individual characteristics of the athlete and, moreover, is sensitive to fluctuations in the athlete's environment (e.g. Hellard et al., 2002). For this reason, the influence of the control parameter training load on the order parameter can be characterized as time-delayed (since adaptive responses are time-dependent) and non-linear. Consequently, the dynamics of the order parameter is relatively stable but not rigid and is not entirely predictable.

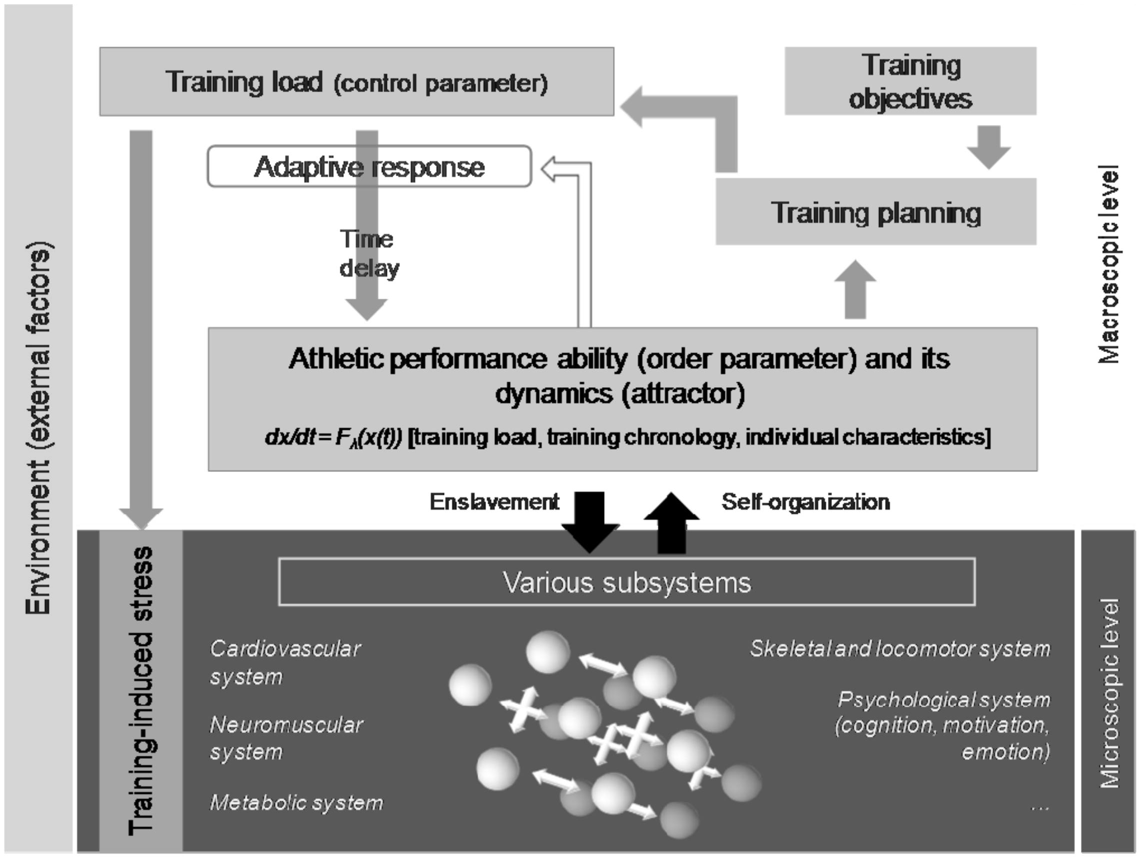

Figure 2. A DST approach to training.

The neuromuscular system can be considered a subsystem of the athlete involved in the training process. Adaptations of the neuromuscular system to strength, power and endurance training are well documented (Hakkinen, 1989; Sale, 1992; Kraemer et al., 1996; Trappe et al., 2001; Neary et al., 2003). These adaptations can be associated with peripheral changes occurring at the skeletal muscle level as well as central changes, which include the neural activation of the motor units of the muscle. With respect to the neural activation, the intermuscular coordination refers to the interaction of the working muscles in a specific movement task, while the intramuscular coordination involves the recruitment, rate coding and synchronization of motor units within one muscle in order to generate force. By means of the surface electromyography (EMG), the activity of the motor units within the range of the detection electrodes can be globally measured. Since the acquired EMG signal depends on membrane properties of the muscle fibers as well as on the timing of the motor unit action potentials, it reflects both the peripheral and central properties of the neuromuscular system (Farina et al., 2004). One EMG signal parameter commonly used is the median frequency (MF) of the power density spectrum. Changes in the spectral parameters have been documented due to peripheral fatigue in the muscle (De Luca, 1984; Balestra et al., 2001), skill acquisition (Bernardi et al., 1996) and adaptations to strength and power training (Moritani, 1992) as well as endurance training (Lucia et al., 2000; Ganter et al., 2007).

Aim of the Study

Despite the common agreement that appropriate frameworks for understanding training and adaptation need to consider the complexity and non-linearity of athletic performance

(Hohmann et al., 2000; 2002; Perl, 2001; Edelmann-Nusser et al., 2002; Hellard et al., 2002; Balague & Torrents, 2005; Pakenas et al., 2007; Pfeiffer, 2008; Jobson et al., 2009), concepts like the proposed DST approach still lack of scientific empirical data and appropriate tools enabling the analysis and evaluation of self-organization phenomena in performance related variables throughout the training process. One explanation is the fact that the use of experimental research procedures is scarcely possible within the context of the training process, not only due to the singularity of the athlete's response and the considerable number of variables involved (Foster et al., 1999; Hellard et al., 2002; Plisk & Stone, 2003). Studies, therefore, need to take the analysis of the individual effects of training into account and should in a first step focus on sports strongly associated with physiological adaptation, like endurance disciplines, in which training and performance are rather accessible for quantification.

Within this study an attempt is made to provide empirical support for the proposed DST approach on the basis of monitoring training and performance development during a ten-week cycling training program, while additionally monitoring changes occurring at the microscopic level in the neuromuscular system.

On the basis of the provided theoretical framework, the following hypotheses are formulated:

1. **Training-performance-relationship:** The relationship between the control parameter training load and the order parameter performance ability is non-linear and time-delayed.
2. **Dynamics of the system:** Stable patterns can be identified in the dynamics of the order parameter as well as phase transitions between intraindividual different stable patterns.
3. **Variability of the system and the subsystem:** The neuromuscular subsystem involved in training exhibits a higher variability compared to the order parameter and the variability is subject to change close to the phase transitions.

Methods

The study used a prospective non-experimental training design in combination with laboratory controlled performance measures.

Participants

Ten Sport Science students (9 male/ 1 female) participated in the study and ranged from recreational cyclists to regional competitive cyclists and triathletes (Table 1). Each participant has signed a written informed consent and was informed about the aim, the test procedures and associated possible risks.

Table 1. Age, sex, anthropometrics, heart rate (resting and maximum value), prior training experience, volume of the training and maximum performance (Pmax) in the first incremental cycling test of the participants.

	Age [years]	Sex	Height [cm]	Body mass [kg]	Rest. heart rate [bpm]	Max. heart rate [bpm]	Training experience [years]	Prior training [hours/ week]	Training volume [hours/ week]	P_{max} [W/kg]
M1	22	m	180	68	55	200	3	4	7	3.9
M2	23	m	200	94	42	197	2	6	6	5.0
M3	23	m	180	77	50	202	2	5-10	10	4.6
W1	26	f	173	62	42	185	-	-	6	3.9
M4	23	m	184	75	48	189	7	5-10	12	4.3
M5	23	m	178	70	50	200	4	10-20	20	4.5
M6	22	m	176	75	58	175	-	-	6	3.0
M7	23	m	180	73	43	202	6	10-20	20	4.7
M8	24	m	188	92	54	192	5	8	8	4.2
M9	22	m	190	85	48	206	3	10	10	4.4

Training

The athletes underwent a ten-week individualized cycling training program aiming at the improvement of aerobic and anaerobic cycling performance. All training sessions were conducted in the field using the cyclists own personal bicycles and the program consisted of periods with varying training volume and intensity. Both aerobic and anaerobic training were performed by using various training methods including continuous, fartlek, interval and speed training, as well as sprints. The particular training schedule was dependent on the performance level and the individual preparation for upcoming competitions (e.g. road race or triathlon), but incorporated in any case high load as well as low load periods. For each training session, the duration, cycling distance, mean exercise heart rate (measured using a Polar S610, Finland) and the type of training (e.g. speed training) were recorded.

For the quantification of the training load, a training impulse score (*TS*), proposed by Banister (1991), which incorporates the duration of the training session (in minutes) and the training intensity, was used. The intensity is reflected by the mean exercise heart rate related to the individuals' resting and maximum heart rate and a gender-specific correction factor, which weights the intensity with respect to the increase in blood lactate during exercise (eqn 1). Despite TS is itself expressed by a non-linear equation, it is used to consider both volume and intensity in one training parameter and since the individual heart rate parameters HR_{max} and HR_{rest} are not expected to significantly change during a ten-week training period.

$$TS = T\,y\,\frac{HR_{ex} - HR_{rest}}{HR_{max} - HR_{rest}} \quad (1)$$

where,

HR_{ex} - mean exercise heart rate [beats • min^{-1}]

HR_{max} - maximum heart rate [beats • min^{-1}]

HR_{rest} - resting heart rate [beats • min^{-1}]

T - duration of a training session [min]

y - correction factor for male (eqn 2) and female (eqn 3) gender (Banister, 1991):

$$y = 0.64\, e^{\left(1.92\, \frac{HR_{ex}\ -\ HR_{rest}}{HR_{max}\ -\ HR_{rest}}\right)} \tag{2}$$

$$y = 0.86\, e^{\left(1.67\, \frac{HR_{ex}\ -\ HR_{rest}}{HR_{max}\ -\ HR_{rest}}\right)} \tag{3}$$

Performance measures

To monitor performance development, a 30-second all-out cycling test (30-s test) on an electronically braked cycle ergometer (Cyclus2, RBM Elektronik Automation, Germany) was conducted three times a week (Monday – Wednesday – Friday), between training week 2 and 10. The test protocol was similar to that of the Wingate Anaerobic Test (*WanT*; Inbar et al., 1996), but in contrast to the *WanT*, the test was performed in isokinetic mode (pedaling rate limited to 110 rpm) and with a flying start, in order to keep the movement velocity constant throughout the test. Power output was sampled at 3 Hz and averaged over 30 s, giving the test performance (*P30*) which was related to body mass (unit: W/kg). *P30* corresponds to the mean power of the *WanT* and can be considered a measure of the actual anaerobic performance, more precisely the anaerobic capacity (Vandewalle et al., 1987; Inbar et al., 1996; Bachl & Baron, 1998), which is known to contribute to cycling performance (Neumann, 1992; Tanaka et al., 1993; Davison et al., 2000; Atkinson et al., 2003). The validity, reliability and sensitivity of the test are discussed in Inbar et al. (1996). The authors state that the test can be regarded valid for the estimation of the anaerobic performance capacity and a sufficient reliability is accomplished through a standardized protocol. Moreover, the *WanT* is also sensitive to changes in performance occurring during certain training regimen. Our previous investigations indicated a very high day-to-day reproducibility of *P30* for the applied test protocol (intra-class correlation = 0.97; Ernst et al., 2008). It should be noted that the 30-s test itself can be characterized as an anaerobic training stimulus with very short duration and maximum intensity but was not considered in the *TS* scores. Own unpublished data revealed no performance improvements in *P30* in a control group with no specific cycling training but only three 30-s cycling tests per week over a period of eight weeks.

In addition to the regular anaerobic performance measures, cycling performance was assessed during an incremental cycle ergometer test (Cyclus2) to exhaustion in week 1 and week 10 of the training program. Blood lactate concentration was determined from capillary blood samples drawn from the hyperaemic ear lobe using a photometric method (Miniphotometer plus LP 20, Hach Lange, Germany) at the end of each increment of the test (starting with 80 W [women] / 100 W [men] followed by 40 W increments every 3 min) and heart rate was continuously measured. The individual anaerobic threshold was obtained using the "+1.5 mmol/l-method" (Dickhuth et al., 1991) and results of the test in week 1 were used to derive the individual heart rate ranges corresponding to different training intensities in order to control the following training sessions. Maximum power output (Pmax) maintained during the last increment was determined as an indicator of cycling performance, integrating the aerobic and anaerobic performance components (Hawley & Noakes, 1992; Balmer et al., 2000; Beneke et al., 2000; Bentley et al., 2001).

EMG measures

During each 30-s test, the surface electromyogram (EMG) of the muscle rectus femoris of the right leg was continuously recorded using a Biovision EMG-system (Germany; analogue RC filter: 10-500 Hz bandwidth, 1000 Hz sampling rate). In order to ensure reproducible EMG measurements, the positions of the EMG electrodes as well as the skin impedance were controlled and standardized. For the analysis, the successive movement cycles (according to one complete pedaling revolution) of the whole test (except the initial and final five cycles) were extracted and the time-dependent EMG power spectra as well as the instantaneous median frequency computed for each cycle by using an autoregressive model (Arnold et al., 1998). Subsequently, the mean median frequency (*MF*) was calculated for each cycle by averaging the instantaneous median frequency over a period of 200 ms when the muscle is active (prior to EMG offset). Finally, for each 30-s test the following parameters of *MF* were obtained, considering all cycles of the test: mean (σ), standard deviation (*SD*) and coefficient of variation (*CV*). This method has been previously used and described elsewhere for the analysis of arm strokes during swim bench testing and has yielded acceptable reproducibility of *EMG MF* in dynamic conditions (Ganter et al., 2007).

Data analysis and statistics

The overall changes obtained in *P30* from the beginning to the end of the training period were compared to the changes in P_{max} in the incremental cycling test in order to evaluate to what extent performance development is comparable between different tests.

The variables used for the analysis of the system's behavior are *P30* (order parameter), *TS* (control parameter) and *EMG MF* (subsystem's parameter). If not otherwise stated, results are presented as mean (*SD*).

Training-performance-relationship. The original time series of *P30* and *TS* were transformed into series containing nine consecutive weeks (week 2 – week 10) with the average of *P30* and the sum of *TS* per week, respectively. Development of performance in relation to training load was illustrated by plotting *P30* vs. *TS* and visually analyzed in each subject.

Dynamics of the system. To analyze the dynamics of the order parameter, the original time series data of *P30* were transformed to a new time scale with a time interval of one day. Since performance was not tested every day, missing performance values between two consecutive tests were linearly interpolated. Transformation and interpolation of the performance data were done for better illustration of the dynamics. Despite the linear interpolation technique may not reflect real performance progress between testing sessions, it seems reasonable since *P30* was assessed very frequent (n = 15-21 tests within 56 days). For the illustration of the dynamics of the order parameter, phase plots were generated with *dP30/dt* vs. *P30(t)*. Different states in the order parameter are qualitatively identifiable as stable patterns in the phase plots and were referred to as *St1* (first state) and *St2* (second state) with the period between the two states is referred to as the phase transition (*PT*; see example data in Figure 3). If different states were identified, the time of *PT* was estimated by analyzing the running total range of *P30* for the nine consecutive weeks (week 2 – week 10), calculated for each week as the range between minimum and maximum value of *P30* in the period beginning with the preceding and ending with the subsequent week. The time of *PT* (within two consecutive weeks) can thus be characterized by a high range followed by an immediate reduction (see Figure 4).

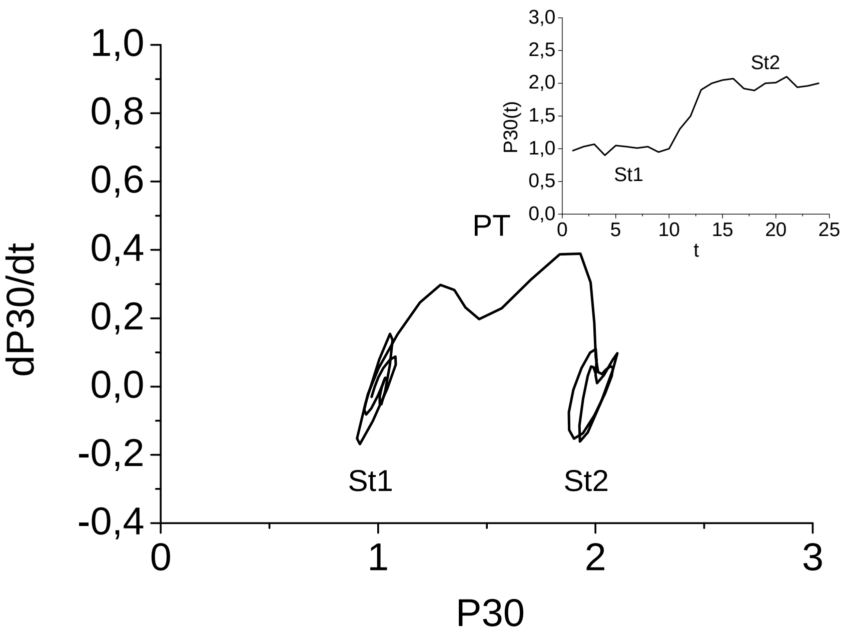

Figure 3. Phase plot of a fictitious time series P30(t) (chart in the upper right). From the phase plots the states of the system as stable patterns (St1 and St2) as well as the phase transition (PT) are identifiable.

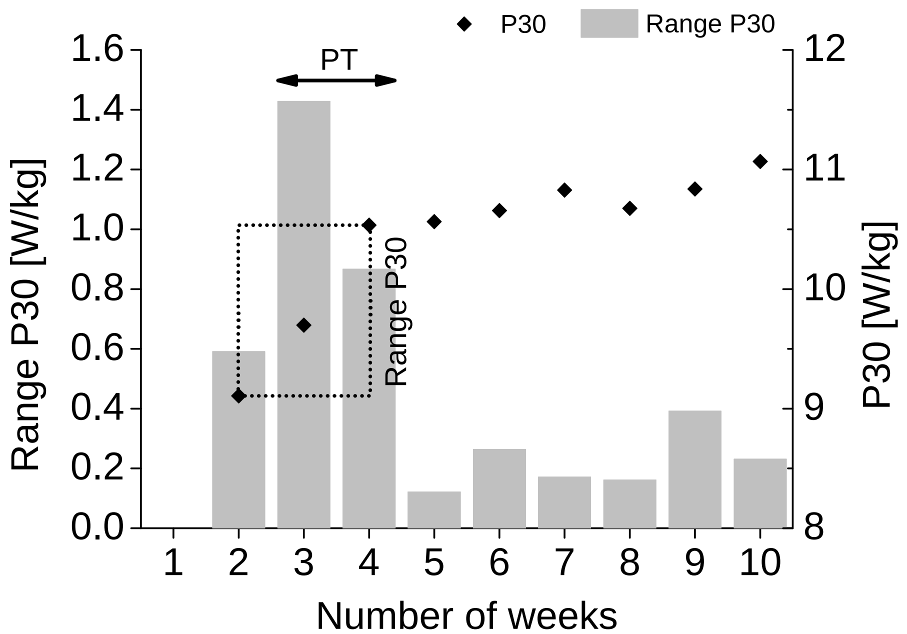

Figure 4. Sample data of athlete M8 showing the running total range of P30 (Range P30: grey bars) and the estimated time of phase transition (PT). The calculation of Range P30 is illustrated for week 3 as the range between minimum and maximum value of P30 in the period between week 2 and week 4. *Example calculation:* Given the values 9.11, 9.70, and 10.53 W/kg for P30 in week 2, 3, and 4, respectively, Range P30 in week 3 is calculated as the difference between maximum and minimum values of P30, namely, 10.53 – 9.11 = 1.42 W/kg. Accordingly, for calculating Range P30 in week 4, P30 values of weeks 3, 4, and 5, namely, 9.70, 10.53, and 10.56 W/kg are considered, giving 10.56 – 9.70 = 0.86 W/kg for Range P30.

Variability of the system and the subsystem. Variability of the order parameter *P30* was determined as the within subject coefficient of variation of all test performances (*CV P30*) during the training period. The variability of the subsystem's parameter *EMG MF* was determined as the within subject average of the coefficient of variation (*CV MF*), calculated for each test as described in the "EMG measures" section. In order to analyze within subject changes in the subsystem's variability close to the phase transitions, all tests in the two weeks preceding the phase transition were compared to the tests in the following two weeks with respect to the *CV* of *EMG MF*.

Results

Overall performance improvement from the beginning to the end of the training period was 14.9 (10.9) % and 8.1 (6.2) % in *P30* and P_{max}, respectively. Participant *M2* was the only athlete with a slightly decreasing *P30* (- 1%), while P_{max} was only slightly increased (2%). The other athletes (*M3, M5*) with a minor P_{max} increase (2%) showed *P30* improvements of 19% and 20%, respectively. The highest improvement in P_{max} was observed for athlete *M1* with 20% combined with a 16% increase in *P30*. Further, the highest *P30* increase of 38% was observed for *M7* coming with a 12% increase in P_{max}.

Training-performance-relationship. Sample data of training load distribution and performance development over the training period are shown in Figure 5 for two athletes, indicating an increasing trend in *P30* and a decreasing trend in *TS* over the training period. The transformation of the data considering *P30* vs. *TS* per week is presented in Figure 6.

Dynamics of the system. The constructed phase plots for all athletes including the identifiable performance states are shown in Figure 7. With respect to the training load distribution, the identified performance states and phase transitions are illustrated for four athletes in Figure 8.

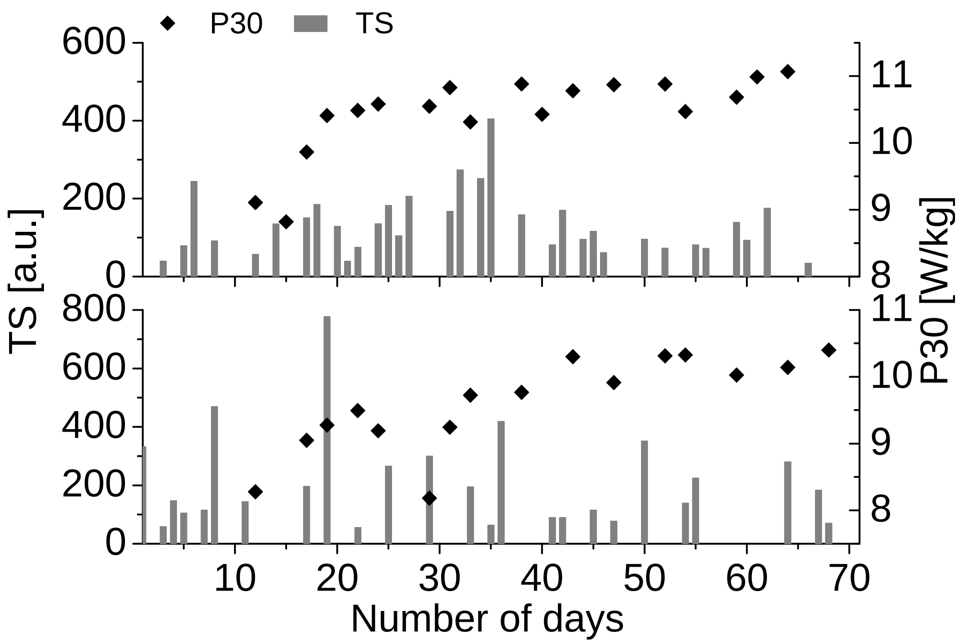

Figure 5. TS (in arbitrary units) and P30 for athletes M3 (bottom) and M8 (top).

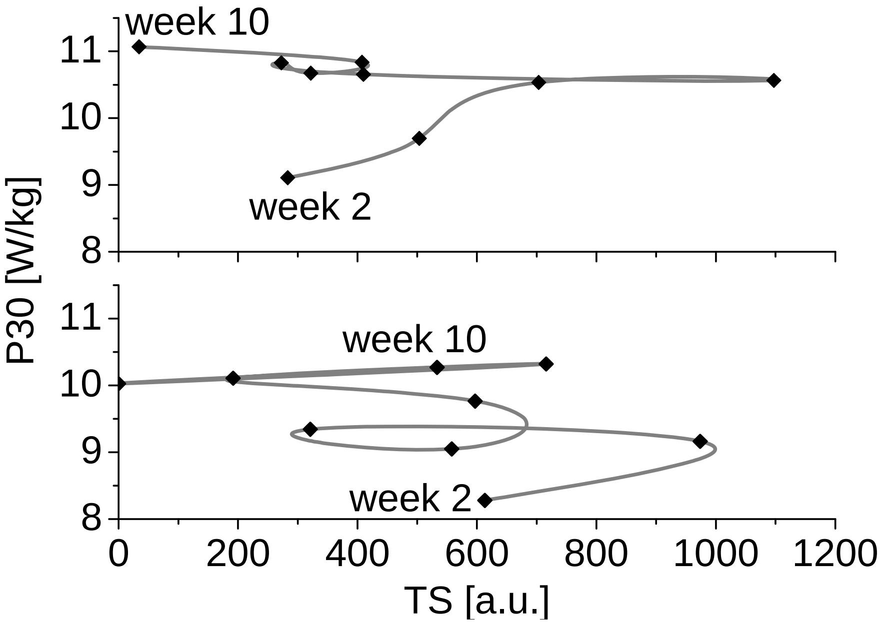

Figure 6. P30 (average per week) versus TS (sum per week) from week 2 to week 10 for athletes M3 (bottom) and M8 (top; grey line: cubic spline curves).

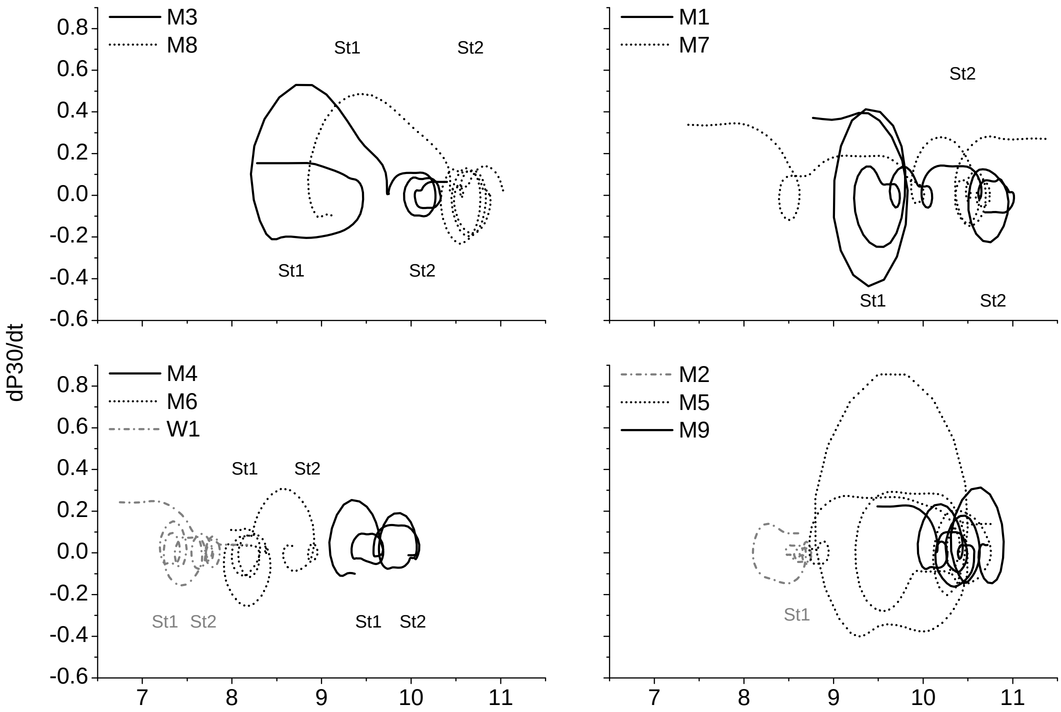

Figure 7. Phase plots (dP30/dt vs. P30) for the athletes M3, M8 (top left), M1, M7 (top right), M4, M6, W1 (bottom left) and M2, M5, M9 (bottom right; cubic spline curves) with the assignment of identifiable performance states (St1 and St2).

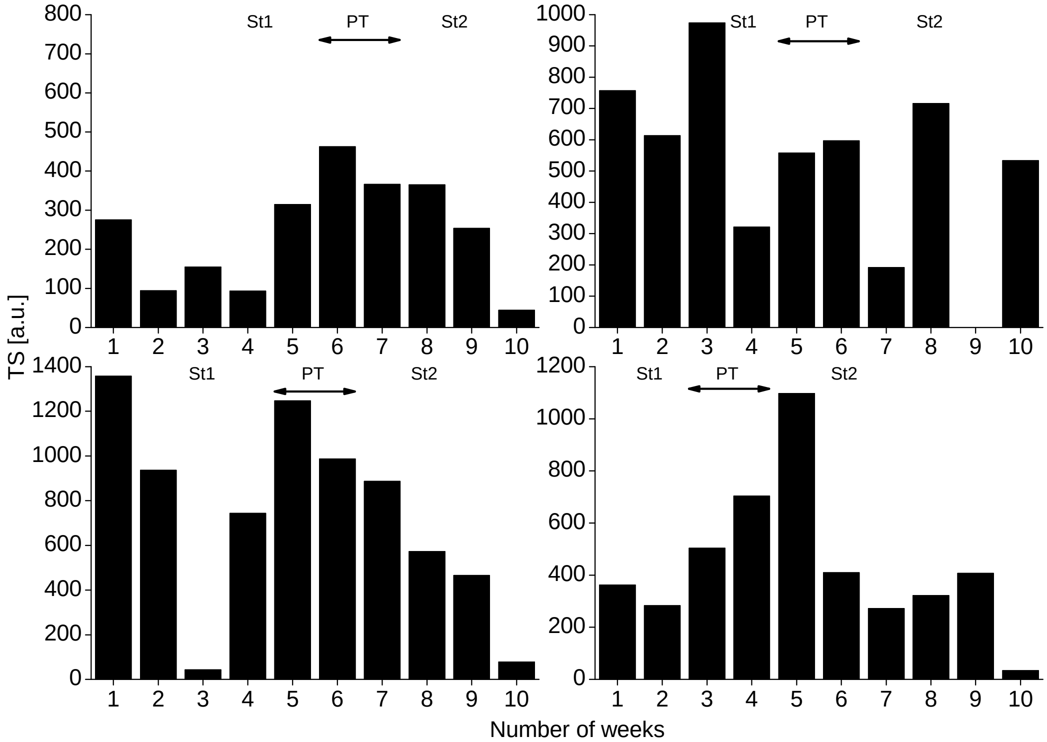

Figure 8. Distribution of TS (sum per week) and time of the estimated phase transition (PT) from state 1 (St1) to state 2 (St2) for athletes M1 (top left), M3 (top right), M7 (bottom left) and M8 (bottom right).

Variability of the system and the subsystem. Variability in *P30* with 5.4 (2.7) % was lower compared to 13.4 (3.0) % in *EMG MF* (Table 2). Table 2 also shows the within subject changes in the variability of *EMG MF* close to the phase transitions.

Table 2: Coefficient of variation (CV) of P30 and EMG MF over the whole training period and EMG MF compared between the tests in the 2-week-period preceding (St1) or following (St2) the phase transition for all athletes.

	CV [%]		St1		St2	
	P30	**EMG MF**	**n**	**EMG MF [CV in %]**	**n**	**EMG MF [CV in %]**
M1	5.7	17.9	5	21.5 ± 3.1	5	20.6 ± 2.7
M2	2.1	10.8	3	17.7 ± 2.6	3	17.7 ± 0.3
M3	7.2	12.3	5	17.2 ± 1.6	3	15.1 ± 2.6
M4	3.0	19.3	3	16.6 ± 2.1	5	18.1 ± 2.4
M5	8.4	11.2	-		-	
M6	4.0	12.9	4	22.6 ± 1.5	3	20.2 ± 2.8
M7	10.5	10.3	4	19.3 ± 1.0	3	17.9 ± 1.8
M8	5.9	14.4	4	20.2 ± 1.6	4	16.9 ± 1.0
M9	3.1	11.5	-		-	
W1	4.1	13.1	5	18.2 ± 3.8	4	20.7 ± 2.7
Mean	**5.4**	**13.4**		**19.2**		**18.4**
(SD)	**(2.7)**	**(3.0)**		**(2.1)**		**(2.0)**

Discussion

Overall performance development. The overall mean performance improvement observed in this study was 14.9% for *P30*. There are only few studies investigating the effects of an endurance training program on anaerobic performance in trained cyclists. A study that utilized the *WanT* found 6% and 3% increase in mean power after four weeks of additional sprint training and endurance training alone, respectively (Creer et al., 2004). Inbar et al. (1996) reported results of different training studies, in which performance improvement after eight weeks of training varied between 7% (not statistically significant) for the moderate aerobic training and up to 20% improvement for the mixed aerobic anaerobic training. Another study of Touchberry et al. (2004) found a non-significant 1% increase in mean power after twelve weeks of training. The results, however, showed large interindividual variations. Direct comparison of our results to other studies is difficult because of the different subject, training and test characteristics.

Compared to the average performance improvement in P30, the increase in the incremental testing performance (P_{max}) was lower (14.9% vs. 8.1%). The differences may be attributed to the specificity of the test, since P_{max} integrates the aerobic and anaerobic component and *P30* mainly the anaerobic component of cycling performance. With respect to improvements or stagnations in performance, the results, however, showed qualitatively good agreement. Since exhausting incremental tests are not feasible for frequently monitoring actual performance during training, the short modified *WanT*-protocol was chosen. There is reasonable evidence for the anaerobic contribution to complex cycling performance, its proportion, however, is largely dependent upon the characteristics of the cycling event and not yet completely understood (Neumann, 1992; Atkinson et al., 2003). Studies with sub-elite cyclists suggest that the higher-level athletes not only provided better aerobic performance but also anaerobic performance as indicated by the *WanT* (Tanaka et al., 1993). The relative *WanT* performance was also found to be a good predictor of hill climb cycling performance in competitive cyclists (Davison et al., 2000).

Training-performance-relationship. Individual performance progressions presented in Figure 5 show typical characteristics of performance curves, with higher variation at the beginning of training, the development of a more stable level after a certain training period and, subsequently, an asymptotic behavior. The representative sample data illustrated in Figure 6 indicate the non-linear and time-delayed characteristics of the relation between training and performance, suggesting that actual performance progression is largely dependent on previous training history. It can be shown that, at the beginning of the training period, performance increases with the training load. A subsequent stabilization and/or further increase in performance are observable once training load is again reduced. The results are consistent with practical experiences and compare well to data shown by Hristovski et al. (2010) illustrating the "memory effect" of training. So at a certain performance level or stage of training, performance tends to increase with training load (Foster et al., 1996). However, the impact of training load has an upper limit above which performance could decline because of accumulated fatigue induced by high load periods (Hellard et al., 2005). By eliminating the accumulated fatigue during subsequent phases of reduced training, effects of lasting performances ("memory effect") or improved performances are well known and used in the tapering periods prior to competitions (Mujika et al., 1996). It has to be noted that no considerable (at least mid-term stable) performance decline was observed in the current study, suggesting that training was not inducing overtraining-like effects (Smith, 2003).

Dynamics of the system. On the basis of phase plots and the running total range of *P30* an attempt is made to describe the dynamics of the system. In fact certain patterns can be observed which may be qualitatively described as the emerging of different states in the performance dynamics (Figure 7). An emerging performance state (*St2*) can be qualitatively characterized by a higher stability (= lower variability) compared to the lower performance states (*St1*) and the phase transition (*PT*) between them. By comparing athletes *M3* and *M8* (Figures 5, 6, 7, 8) the emergence of the higher stable state (*St2*) occurs earlier in the training period for *M8*, with the attribution of the first state (*St1*) to the initial performance level, but without exactly knowing how stable this first state in the long-term has been for *M8* beforehand. Nonetheless, a transition early in the training period, here referred to as a phase transition can be observed. By quantitatively analyzing the performance dynamics, the periods of emerging states or the phase transitions between different states may be allocated. The results show that if different performance states are identifiable, the occurrence and time frames of the transition periods are highly individual. With respect to the current training load, with the weekly *TS* scores comprising volume, intensity, and frequency of training, phase transitions could be attributed to periods with moderate loads either following high or reduced load phases (Figure 8). In addition, they could also be allocated to high load periods, suggesting that the occurrence is, among other things, influenced by performance level and training history. Keeping in mind that the *TS* score does not discriminate between the contributions of volume, intensity and frequency to training load, *PT* for *M8* may be attributed to the period when training load increases and, therefore, becomes effective, whereas for *M3* the *PT* may be observed not until training load is sufficiently reduced (Figures 6 and 8). Other qualitative patterns observed were, first, leaving a stable performance state towards the end of the training period (athlete *M2*) and, second, the non-occurrence (or non-identifiability) of at least mid-term stable performance states (athletes *M5*, *M9*; Figure 7). In the first case, the pattern may result from the excessive reduction in load towards the end of the training, leading to a preliminary stage of detraining (Neufer, 1989). For the second case, one may speculate that other stressing factors than training load are the reason for short-term fluctuations in performance and thus preventing the emergence of a stable state. However, this cannot be fully addressed with the available data.

The concept of identifying performance attractors has been used in studies by means of neural networks (Hohmann et al., 2000; Edelmann-Nusser et al., 2002). Despite these studies were able to model competition performances of elite swimmers, the temporal characteristics of the performance states have not been addressed. Analyses of frequent performance measures in the training of swimmers revealed differences in the dynamics of emerging performance states between elite and junior athletes also highlighting the specificity of responses to training (Ganter et al., 2008; Witte & Ganter, 2010). A recent work by Hristovski et al. (2010) observed collective variables (order parameters) at different levels of exercise-induced psychobiological adaptation, namely, at performance, electrophysiological, kinematic, and psychological level. They showed phenomena indicating the self-organized evolution of soft-assembled cooperative states on different time scales under the control of constraints (control parameters), for instance, in the study of fatiguing exercises.

Variability of the system and the subsystem. The variability in the order parameter (*P30*) has shown to be lower than in *EMG MF*, as a measure of variability in the subsystem, for nine out of ten participants (Table 2). Only for athlete *M7* the variability was quite similar, which may be attributed to the high performance improvement observed. When interpreting the differences, the proportion of variability induced by the measuring method, needs to be taken into account. Due to the stochastic nature of surface EMG signals, some natural variability in *EMG MF* can be expected. Previous studies, however, indicated acceptable reproducibility of the method used (Ganter et al., 2007; Ernst et al., 2008).

With respect to the within subject changes of the variability in the subsystem, the results indicated a trend of reduction for *EMG MF* after the phase transition in five out of eight participants, in which different performance states were identifiable (Table 2). Changes in EMG spectral parameters in the course of endurance training have been reported (Lucia et al., 2000; Ganter et al., 2007) and can be associated with morphological adaptation of the skeletal muscle and adapted neural activation also occurring in cycling training (Hawley & Stepto, 2001). Despite several factors influence the characteristics of the surface EMG signal and, therefore, need to be controlled, the signal reflects to some extent the function of a part of the neuromuscular subsystem.

Practical implications for training. This study aimed at analyzing data of a cycling training program in order to evaluate whether it provides support for a DST approach to training. Cycling in a first instance was chosen, because cycling training can be strongly associated with physiological adaptation and training and performance parameters are quantifiable. Consequently, the results of the study have no direct practical implications for the training in cycling. Rather, the DST approach and the concept of self-organization of performance states in the training process would have some practical implications on training planning. With regard to this concept, Hohmann et al. (2000; 2002) state that a certain range should exist for training loads to be appropriate to initiate self-organization of the transient state of optimal performance in the particular athlete. Consequently, a too detailed prescription of training load is not necessary as long as the individual responses to the training stimuli will be continuously evaluated. Similarly, Hellard et al. (2002) summarize that adaptational responses to training are always specific to the individual athlete and, to a certain extent, unpredictable. Accordingly, they demand to reconsider the “closed” classical planning models to an open conception of planning, which "implies ... the development and regulation of the initial strategy in accordance with the unforeseen emergence of adaptational responses ... and in accordance with the unpredictable evolution of the athlete's overall environment" (Hellard et al., 2002, p. 87).

Limitations of the study. Limitations of the study can be seen in the non-experimental training design and the methods used for assessing training and performance. The observational approach in cycling training combined with an exploratory data analysis does not allow to confirm, but rather to support or non-support the stated hypotheses. Consequently, generalization of the findings is limited, unless tested in other settings (sports and athletes). Despite these limitations, observational studies are necessary in the context of training processes of elite athletes, since experimental procedures are scarcely possible due to the singularity of the athlete's response and the considerable number of variables involved (Foster et al., 1999; Hellard et al., 2002; Plisk & Stone, 2003). Further limitations can be associated with the method used to quantify training load and performance in cycling as well as the EMG procedures used to infer adaptation of the intramuscular coordination. Despite endurance sports like cycling are advantageous for assessing training loads compared to more technique-oriented sports, the approach used to calculate the training impulses on the basis of heart rate responses has some shortcomings when assessing high or intermittent intensity training. Under the assumption that, if macroscopic patterns exist in the dynamics of the complex performance ability, they should also be identifiable in the dynamics of the anaerobic component of performance, the proposed test procedure to assess performance has been used under practical considerations with the previously discussed limitations in validity.

Future studies. For further verification of a DST approach to training, systematic prolonged analyses of training processes in different sports with athletes at various performance levels are necessary. To enable quantitative analyses also in elite sports, training and performance parameters are required to be monitored continuously with least disturbance to the training process. Therefore, technical advances would be valuable like, for example, the recent development of cycling power output measuring devices that enable training and performance assessment even under field conditions. On the basis of such data, retrospective analysis of critical training periods is possible which cannot be adequately mimicked in experimental approaches. Following a holistic perspective, the integration of assessing additional physiological, psychological and social parameters is necessary in order to identify further key variables characterizing different performance states. To further the systems modeling of the training-performance-relationship non-linear methods like, for example, PerPot, fuzzy logic or neural networks (Balague & Torrents, 2005) can be valuable for analyzing data related to training processes.

Conclusion

This study tried to evaluate whether training and performance data obtained from a group of cyclists during a ten-week cycling training program support a proposed DST approach to training. The results suggest that, at the macroscopic level, performance development observed during the training program shows, to a certain extent, a self-organizing behavior that can be characterized by stable patterns in the performance dynamics, described as performance states and transitions between these states. Further, the analysis at the microscopic level, in terms of spectral EMG parameters, at least in part supports the hypothesis that changes are observable close to the phase transitions. A DST approach may have direct implications on concepts of training planning and the identification of performance states in training in order to optimize training and performance response in the particular athlete in a next step. However, to bring forward a viable framework for training and adaptation, the search and study of self-organization phenomena in the adaptive behavior of the athlete needs to be continued, by identifying potential collective variables or order parameters reflecting macroscopic changes under the influence of control parameters. Moreover, suitable tools need to be developed or utilized to enable extensive analysis of training processes, particularly for elite athletes, in various sports in order to further the understanding of the training-performance-relationship.

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Sport Coaches Use of Cloud Computing: From here to Ubiquity

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Abstract

Cloud computing is providing sport coaches with opportunities to transform their work with athletes. This paper identifies characteristics of Cloud computing and discusses sport coaches' use of the 'Cloud'. Examples are presented of this use in the sport of canoeing in Australia. The paper examines some of the risks inherent in a move to Cloud computing whilst acknowledging the dynamic possibilities available from new ways of communicating. The paper concludes with a discussion of the use of iterative 'good enough' approaches to digital repositories.

KEYWORDS: CLOUD COMPUTING, COACHING

Introduction

This paper discusses sport coaches' use of Cloud computing resources to support their professional development and their work with athletes to enhance performance. The argument presented here is that "convenient, on-demand network access to a shared pool of configurable computing resources" (NIST, 2009) combined with the emergence of an open-access movement that provides a "dynamic, communally constructed framework of open materials and platforms" (Vest, 2006) enrich and transform the coaching process.

At the outset it is important to define three key terms. The 'Internet', the 'World Wide Web' and 'Ubiquitous Computing' are essential to an understanding of Cloud computing.

Wikipedia (2010a) defines the Internet as "a global system of interconnected computer networks that use the standard Internet Protocol Suite (TCP/IP) to serve billions of users worldwide." It is a "network of networks that consists of millions of private, public, academic, business, and government networks, of local to global scope, that are linked by a broad array of electronic and optical networking technologies."

Twenty years ago Berners-Lee and Cailliau (1990) proposed a project in which HyperText would be used as "a way to link and access information of various kinds as a web of nodes in which the user can browse at will." The project aimed to provide "a single user-interface to large classes of information (reports, notes, data-bases, computer documentation and on-line help)." The World Wide Web today is "a system of interlinked hypertext documents accessed via the Internet" (Wikipedia, 2010b).

In this paper the term 'ubiquitous computing' is synonymous with 'pervasive' and 'mobile' computing (Börner, Kalz, and Specht, 2010) and signifies a third era of modern computing (Want, 2009). The use of the descriptor 'ubiquitous' acknowledges the role Weiser and his colleagues (Weiser, Gold, and Brown, 1999) played in conceptualising and operationalising "a new way of thinking about computers in the world, one that takes into account the natural human environment and allows the computers themselves to vanish into the background" (Weiser, 1991). Sport coaches' use of ubiquitous computing is informed by a "vision of small, inexpensive, robust networked processing devices, distributed at all scales throughout everyday life and generally turned to distinctly common-place ends" (Wikipedia, 2010c). This ubiquity is moving to a state where technologies "weave themselves into the fabric of everyday life until they are indistinguishable from it" (Weiser, 1991).

Cloud Computing

In a recent report on the future of cloud computing, Pew Internet (2010) point out that the 'Cloud' is used as a metaphor for the Internet. They suggest that 'Cloud Computing' is a phrase used to "describe the act of storing, accessing, and sharing data, applications, and computing power in cyberspace". Cloud architectures allow users to access: storage and computing power; centrally located information reachable through any compatible device; and social information exchange. Cloud computing enables "convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction" (NIST, 2009).

The Horizon Report (2009a) notes "the *cloud* is the term for networked computers that distribute processing power, applications, and large systems among many machines". The Horizon Report (2009b) adds that Cloud computing makes it possible "for almost anyone to deploy tools that can scale on demand to serve as many users as desired. To the end user, the cloud is invisible; the technology that supports the applications doesn't matter — the fact that the applications are always available is key. Data storage is cheap in these environments ... so cheap that it is often provided in surprising quantities for free".

The Cloud provides extensive opportunities for information browsing, seeking, searching, chasing (Anderson, 2010). Siemens (2010) identifies the importance to be attached to splicing and switching behaviours that give individuals control over how they encounter "information and social relations in different circumstances and for different purposes". A decade ago, Pirolli and Card (1999) discussed the characteristics of 'information foraging' and concluded that "people adapt to the constraints and problems they face in complex, dynamic, often technology based environments in which they perform tasks that require processing external information-bearing resources." Rheingold (2009a, 2009b) notes how 'network literacy' has transformed our ability to use the underlying technical architecture of the Internet to support the freedom of network users to innovate.

Sport coaches and those who work to support them have increasing amounts of digital resources to access and share. The maturation of the World Wide Web, the emergence of a vibrant open access movement and the diversity of Cloud computing capability create unprecedented opportunities to develop sport coaching. Vest (2006) observed that "in the open-access movement, we are seeing the early emergence of … a transcendent, accessible, empowering, dynamic, communally constructed framework of open materials and platforms … the Internet and the World Wide Web will provide the communication infrastructure, and the open-access movement and its derivatives will provide much of the knowledge and information infrastructure."

Clarke (2009) describes how smart phones exemplify Cloud opportunities. He suggests "Current generation smart phones, including the iPhone 3Gs and Motorola's Droid, contain all the technology necessary to connect the Web and the physical world". These phones have: a camera; a Global Positioning System; a compass; a mobile data connection to the Web; a display; and a mobile Web browser. Clarke (2009) argues “Any mobile device with these five technologies—and the right software—can retrieve information about the physical world just by pointing at a nearby object. The GPS system knows where you are, the compass knows what direction you are facing, and the camera knows what you are aiming at. The mobile data connection can then retrieve information based on these coordinates and display it on your device”. A sport coach with a mobile phone can retrieve information gathered at a location and add to it. The possibilities are very exciting as Clarke (2009) asserts “ all object- or location-specific data already collected and published in scientific journals and books can be extracted and linked to the relevant coordinates. Instead of performing a complex literature search, imagine simply pointing your mobile device at an object and retrieving all data ever collected about that object.” Traxler (2009) has identified the move from short-term trials to blended deployment of mobile systems in education and there is every reason to believe that sports coaches are at the forefront of these deployments.

Managed Risk

Pew Internet (2010), amongst others, notes that the availability of Cloud resources opens up “a wide variety of reliability, interoperability, privacy, and security concerns, as people put their information under the control of strangers in remote location anytime they trust in the cloud.” It is important that sport coaches acknowledge these risks and manage their use the Cloud appropriately (Oh, Lim, Choi, Park, and Lee, 2010). Sport coaches who access and use institutional computing facilities need to be aware of some of the security constraints they will face in complying with institutional software provision. Those sport coaches who work within national government organisations have important code of practice behaviours to follow (Paquette, Jaeger, and Wilson, 2010).

The dynamic nature of Cloud computing will require institutional providers of Internet services to adapt to the opportunities that will become available. Mobile sport coaches will be a catalyst for the change in use of these resources. Whatever support a sport coach receives he or she will need to be clear about the importance of immediate or long-term access to the resources that are stored in the Cloud rather than tethered to a specific location. In many sport institutes around the world there is a growing number of educational technologists who support sport coaches and their ubiquitous use of the Cloud (Lyons, 2010a).

A decision to store resources in the Cloud must be informed by an understanding that there is no guarantee of permanence for these resources. In the last year (2010) the decision by the social network provider Ning to move from a free service to a subscription service left a number of social network groups with a dilemma about how to sustain communities online (Lyons, 2010b). Doubts about the future of Del.icio.us, a social bookmarking service, sent enormous shockwaves through an online community committed to sharing links.

Sport Coaches Using the Cloud

The proliferation of Cloud architecture has meant that sport coaches can access a wide range of services. Pew Internet (2010) note that “email, word processing, spreadsheets, presentations, collaboration, media editing, and more can all be done inside a web browser, while the software and files are housed in the cloud”. They add that productivity applications services like Flickr, YouTube, and Blogger, amongst others, “comprise a set of increasingly powerful cloud-based tools for almost any task a user might need to do” (see Diaz, Salmons, and Brown (2010) for further discussion of these productivity applications).

The availability of Cloud computing resources has accelerated the process and practice of disintermediation (Wikipedia, 2010b). Sport coaches can produce, edit, mix (mash) and share resources between themselves and athletes without relying on others to load this material for them. Eckel (2009) notes that the "Internet takes a formerly expensive cost (communication) and drives it to essentially zero. Any activity where communication is important is being disrupted". In his discussion of schools, Tucker (2010) observes that there will always be physical schools but these schools "will evolve into things that look more like civic centres - hubs for community involvement and rich relationship-building, augmented by more spontaneous micro-communities that span the globe, forming and bursting like soap bubbles". The application of this approach to sport clubs and sport coaches extends these trends.

Some sport coaches have become produsers in the Cloud, other coaches have been supported in their creation and sharing content. Burns (2007) points out that in collaborative communities "the creation of shared content takes place in a networked, participatory environment which breaks down the boundaries between producers and consumers and instead enables all participants to be users as well as producers of information and knowledge - frequently in a hybrid role of *produser* where usage is necessarily also productive".

Examples of Coaches Using the Cloud

Many sport coaches innovate in their use of information and communications technology. In Australia, for example, coaches have a long tradition of using video and computer technology (Lyons, 2002). In the last decade this innovation has accelerated and made increasing use of the Cloud resources available.

The sport of canoeing provides an interesting example of this use. In Australia, the organisation responsible for the sport is Australian Canoeing. Its current web presence dates back to June 2001 with a searchable archive of news items. Australian Canoeing changed its Internet Service Provider in 2004 in order to provide an integrated service to the sport's membership including its coaches.

Until 2008, Australian Canoeing used its web platform as the content management system for the sport. A small number of people had permission to upload content. Australian Canoeing's Webmaster coordinated all upload. In 2008 Australian Canoeing established its own wiki presence. The wiki emerged as a grassroots response to a trend identified by Stanley (2009). He points to "motivated amateurs who voluntarily produce knowledge and information in a new form of social and managerial organisation". This 'wiki-ised' community: "is a platform; is permeable; consists of voluntary and self-organising associations and content providers; is governed by protocols based on community values; encourages play (and even failure); is governed by "intellectual barter" and makes all knowledge created therein free to anyone; is managed by administrators who "bubble up" from among the members of the community; is managed by administrators who maintain the platform as "choice architects" and lead via cultivation and care, not command and control, and has a fluid temporal structure" (Stanley, 2009).

One of the first pages on the Canoeing wiki was a Coaching page. Since that time the page has linked coaches and enabled them to become produsers (Burns, 2007). In 2010 the wiki was used as the live platform for an Oceania Coaching Conference (Figure 1).

Figure 1: Oceania Coaching Conference 2010 wiki page (http://csaus.csp.wikispaces.net/Oceania+Coaching+Conference+2010).

The conference used the microblogging service Twitter and the live messaging service ScribbleLive to provide information to colleagues across the region. Both these systems used the #OCC10 tag to ensure that an Internet search could find this information. All presenters agreed to their presentations being shared openly with a Creative Commons Attribution License 3.0. This license gives users permission to copy, transmit, distribute and adapt the work "in the manner specified by the author or licensor (but not in any way that suggests that they endorse you or your use of the work)". Coaches are using the material stored on the wiki to inform their planning of programs for athletes.

Following the establishment of the wiki in 2008, Australian Canoeing started to explore other social media available as a Cloud resource. In the last two years the official web site has acted as a point of reference for a Facebook page, a Twitter account, a YouTube Channel and a Flickr page (Figure 2). The site uses Really Simple Syndication (RSS) to offer members the opportunity to receive updates. Sport coaches have become important users of these services. They direct athletes to these social media and use them for remote access whilst away from their home training environments.

Figure 2: Social Media links at http://canoe.org.au/.

The YouTube channel (Figure 3) contains a mix of high quality videos produced for television broadcast and a range of coach-produced resources.

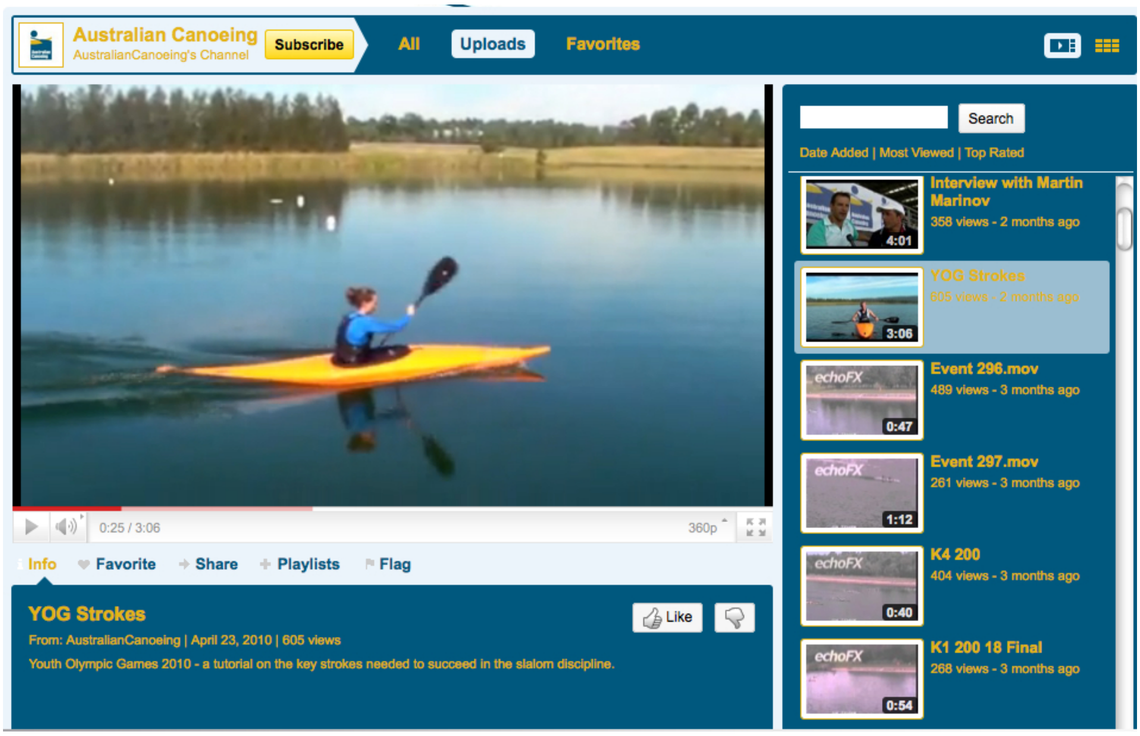

Figure 3: YouTube Channel http://www.youtube.com/profile?user=AustralianCanoeing.

Australian Canoeing's use of social media is following a path collaborative learning and collaborative knowledge production identified by Tapscott and Williams (2010): content exchange; content collaboration; content co-innovation; knowledge co-creation; and collaborative learning connection. It is the process described by the Institute for the Future (2005): "when social communication media grow in capability, pace, scope, or scale, then people use these media, communication techniques and tools to construct more complex social arrangements and practices that increase human capacity to cooperate at larger and larger scales".

'Good Enough' Approaches

Sport coaches tend to be early adopters of technological innovation. Rogers (1962) suggests that early adopters exercise judicious choice of what to adopt to help them maintain a central communication position. Sport coaches are prepared to experiment with information and communications technology and do so in 'good enough' ways.

Lund (2009) characterises 'good enough' iterative use of digital repositories as a community response to user needs with existing available tools. Sport coaches seek out tools that they think will enhance their coaching. As produsers they are much more likely to use a folksonomy approach (Vander Wal, 2007) to data storage, sharing and discovery rather than formal metadata standards. A folksonomy is based on personal free tagging of information and objects for one's own and others' retrieval. This tagging is derived the produser's own vocabulary.

This 'good enough' process is fallible and often requires the support of colleagues who can help with the messiness of early adoption. An example of this approach is the use of Flickr by coaches at a workshop for canoe slalom. Sport coaches at the workshop were interested in using photographs to stimulate discussion about technique. Shortly after the workshop I posted the photographs to an existing Flickr account for them (Figure 4). The images provided an immediate discussion point about Flickr as a tool and a novel way to engage with athletes. The photographs had a short-lived use but remain as a repository for coaches to use on an as need basis.

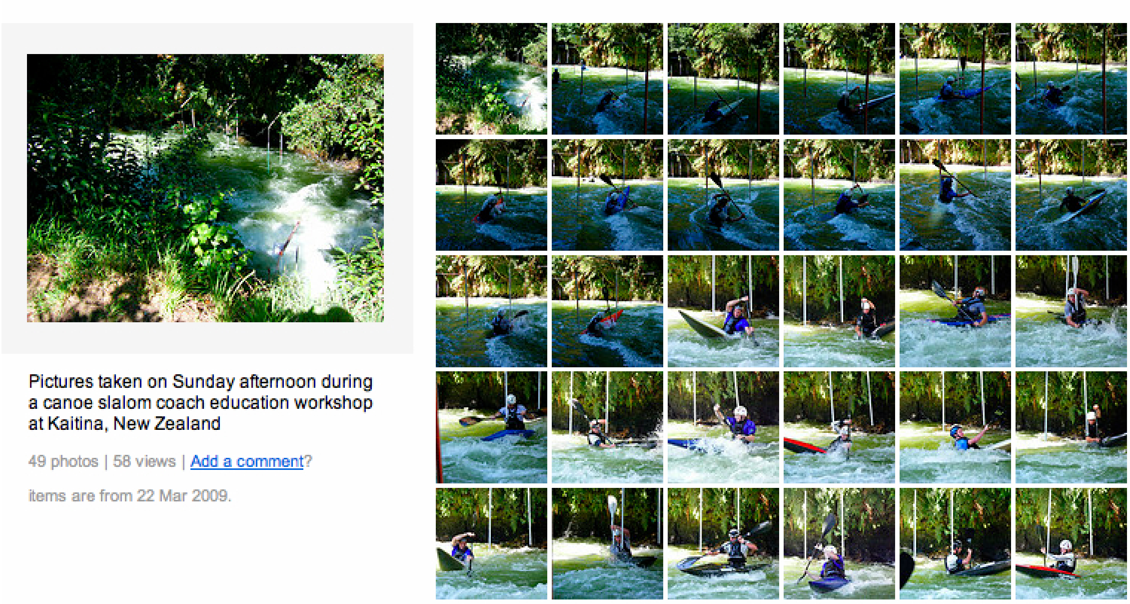

Figure 4: Flickr Album http://www.flickr.com/photos/clydestreet/sets/72157615744717728/.

Discussion

In the period between the submission of this paper for review and its review a number of new Cloud services appeared (for example, Amazon's Cloud Drive and Player). Their arrival underscores how dynamic this space is.

To date there is very little published evidence about sport coaches' use of Cloud resources. Link and Lames (2009) point to the trend in the use of Cloud computing. Kivinen, Hedman and Kaipainen (2009) demonstrate a sport-specific case of real-time documentation and on-site analysis. Their system is based on Cloud computing and a software as a service application. More recently, Obst (2011) has identified a range of Cloud services that can be used by sports medicine practitioners.

Vondrick, Ramanan and Patterson (2010) exemplify how Cloud resources and crowdsourcing can be used to support sport coaches. They report their use of Amazon's Mechanical Turk to develop a human intelligence task to annotate video. They note the potential of this approach to deal with real-world data sets and point to an "inherent trade-off between the mix of human and cloud computing used vs. the accuracy and cost of the labeling".

There is substantial anecdotal evidence about the increasing use of Cloud computing resources by sport coaches. These resources offer sport coaches remarkable opportunities to develop their own practice and create rich learning environments for athletes. Some sport coaches are making use of these resources themselves whilst Internet-aware colleagues are supporting others. This paper has provided some examples of this use in the sport of canoeing in Australia.

This paper has focussed specifically on the use of generic and open Cloud resources. Many suppliers of proprietary software for sport are offering Cloud capabilities and capacities for their services. In Australia and elsewhere coaches and athletes are accessing products and services such as Garmin Connect™, Kinetic-Athlete™, SportsCode Cronus™ and Dartfish TV™. As with the generic services available in the Cloud, dedicated sports applications raise the questions of security and accessibility. It is clear that in the immediate future all users of sport specific applications will need to address the fundamental issues of creation, consumption and curation (Solis, 2010) whether they are using fee for service applications or open access media. It is evident too that those coaches who develop risk management strategies are becoming early adopters and innovative users of Cloud computing.

Conclusion

The Cloud is delivering "convenient, on-demand network access to a shared pool of configurable computing resources" (NIST, 2009) to sport coaches. This shared pool is offering subscription services and open access resources. The convergence of technologies that was a possibility a decade ago (Lyons, 1998) is now providing mobile coaches with ubiquitous access to platforms and resources. Cloud computing has become a synthesis of mobile, pervasive and ubiquitous computing and is a term that is in widespread use.

Sport coaches and their helpers are building their practice through the use of iterative 'good enough' approaches to digital repositories. They are prepared to trade off long-term permanence for short and medium-term benefit. Many of them are managing the risk of using the Cloud and are doing so in a way that is transforming the coach-athlete relationship in a digital age. This is fallible, exciting activity characteristic of *"sudden efflorescence"* (McGilchrist, 2009) and of sport coaching itself.

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Real-Time Training and Coaching Methods Based on Ubiquitous Technologies – An Illustration of a Mobile Coaching Framework

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Abstract

Ubiquitous methods and technologies are well-established in modern society. Pervasive computing techniques are also widely used in the field of sport. This article gives an overview of some typical implementations and fields of application regarding the use of pervasive computing in sports competition and training. Moreover, it presents our current focus on the field of "Mobile Coaching" as one specific ubiquitous approach. This includes our research goals and objectives as well as the methodology, practical scenarios and implemented results of the framework.

KEYWORDS: UBIQUITIOUS COMPUTING, ANT, SENSOR TECHNOLOGIES, FEEDBACK

Introduction

The fields of computer science and particularly the branches of communication and information technologies have made a huge progress during the past decade. The Internet and more precisely the World Wide Web have become more and more widespread, counting billions of users nowadays. Mobile devices like smartphones were invented and are used these days not only as telephones or organizers, but also for many additional purposes like capturing pictures or listening to music, just to mention few. Moreover, the advances in the field of mobile software development bring great opportunities and a new boom for the design of extensive mobile applications. And although this was not conceivable 10 years ago, in the meantime the above listed inventions are well-established in our scientific world and have become part of modern life style and research today.

This current tendency of ubiquitous or also called pervasive computing describes exactly the movement of information processing towards miniaturized, interconnected and intelligent computer devices as integrated part of every day life. Moreover, the concept specifies the modern way of human-computer interaction based on embedded systems, objects and activities. The increasingly powerful, sophisticated, networked and smaller developments of today's pervasive computing technologies lead to an invisibility and unawareness of their actual use. Therefore, the omnipresence of this paradigm is sometimes also referred to as "The Internet of Things", "things that think" or "ambient intelligence".

As a consequence of the fast moving trend, ubiquitous technologies are meanwhile widely applied in the field of sport as well (Baca, 2008b; Baca et. al, 2009). Even more, nowadays the integration of pervasive methods and systems is seen as an essential part of the coaching, training as well as competition processes. Some of the most current examples of application are presented in the next chapter. Our research goals and methods including the concept of our mobile coaching framework are described thereafter, followed by current implementation results, discussion and final conclusions.

Available Frameworks – State of the Art

The constant developments in computer science enable many new opportunities for the measurement, acquisition, collection, transfer, processing and analysis of sport-specific data. Particularly the advances in sensor, information and communication technologies in conjunction with highly evolved and miniaturized constructions, increasing process power as well as higher data and transfer rates, provide nowadays promising means for the analysis of data in sports in almost real time (Chi, 2008).

Competition

Regarding professional sports competition, the Hawk-Eye framework (Figure 1) is one specific example that illustrates the strong application potentials of novel technologies in sports. The system determines and tracks the trace of the ball in near real time based on recordings from high speed cameras and implemented triangulation methods (Sherry & Hawkins, 2001). It is mainly applied in cricket but also in tennis, where it was first introduced in 2002 as (among other functionalities) decision-making aid for the main umpire in controversial situations, detecting whether the ball is inside or outside of the court. In addition to the novel methodology, another particular characteristic for the pervasive method is that the spectators are actually not directly aware of the presence of the system.

Figure 1. The Hawk-Eye system used in cricket and tennis (Hawk-Eye Innovations, 2011).

In other sports like for instance soccer similar solutions have been repeatedly considered and discussed but not yet introduced. While some approaches propose goal-line technologies based on video cameras and instant replays (D'Orazio & Leo, 2010) others suggest the implementation of an embedded RFID chip inside the ball (e.g. the already available smart ball from Adidas®) for tracking purposes (Kapadia & Chimalapati, 2011). However, such methods are opposed by some key decision makers in soccer.

Coaching and Training

Meanwhile, the Hawk-Eye Innovations Ltd. company has also released explicit coaching versions of their system, representing "the most technologically-advanced high performance coaching systems in the world". It allows a full analysis of the cricket and tennis players' performances, including training and technical support as well as biomechanical evaluations.

Consequently, other important fields of application of pervasive computing in sports involve the training and coaching process. The great benefits of today's ubiquitous technologies are their networking abilities and miniaturized appearance (Link & Lames, 2009), making them easily applicable during training sessions and, hence, allowing a less interfering way of measuring different kind of sport-related parameters.

Recently, many innovative approaches for the monitoring of sports performances have been implemented, supporting athletes and coaches in their training and coaching behavior. Especially in common sports such as running and cycling a number of frameworks are currently in ongoing development. Several modern software tools like for instance the Adidas® MiCoach program (http://www.micoach.com) have been implemented to evaluate the running data locally on the mobile device (currently available for iPhone and BlackBerry). In Jaitner & Trapp (2008), on the other hand, an intelligent system based on a service-oriented architecture for the optimization of team training in professional cycling is proposed.

As a particular example, current research focuses on the development of performance-based feedback systems in sports (Baca, 2008a; Baca et al. 2010). The high importance of immediate return of feedback information to the athlete has been proved by different studies (e.g. Schmidt, 2005). One specific concept, where pervasive information and communication technologies are applied for the support of the athletes' workouts as well assistance of their coaches and other specialists, is sometimes also stated as "Mobile Coaching" (Baca & Kornfeind, 2009; Novatchkov et. al, 2009). The main idea thereby is to provide remote analysis and feedback routines based on the integration and implementation of mobile wireless techniques (Novatchkov et. al, 2010).

In competitive sports such methods may be employed for the analysis and enhancement of the athlete's performances. Advanced feedback systems could be also integrated in the preparation process and used, among others, for the evaluation of the quality of the movement during training. Another study (Ghasemzadeh et. al, 2009), for instance, suggests a wearable framework on the basis of integrated body sensor networks which analyses golf swings and provides feedback on the motion sequences.

In addition, though, such feedback systems may be also useful for preventative purposes. In particular, they may be applied for the intention of avoiding overstrain but also underload. Such prophylactic implementations may then involve a lowering of the risk of injuries for both competitive and recreational athletes. A mobile analysis approach advising pupils during physical exercise is proposed in Preuschl et al. (2010). Since also the motivation factor plays a crucial role in the design of such feedback systems, another practical application includes the encouragement of less sportive people in doing more sports or at least being more active.

Research Goals and Objectives

Our main research aim is to implement a mobile coaching and training framework for the remote analysis of performance data and generation of personal as well as automated feedback notifications based on the integration of ubiquitous technologies such as wireless sensors and mobile devices. For these purposes, the system should have the following basic requirements regarding the usability of the feedback application:

- Mobility
- Low power consumption
- Minimal interference with the athlete's training
- Convenient integration facilities
- User-friendly design and easy usage
- Clear presentation tool

Moreover, it is important that the system is preferably generic for different application areas and hence easily adaptable for various sports sectors. This includes also the implementation of common handheld PCs and sensor technologies, which may be easily applied in widespread fields.

In terms of the technical realization, the main focus is set on the development of efficient methods for the measurement, collection and bidirectional transmission of relevant performance data to the remotely located experts as well as crucial feedback information to the athlete, including the following hardware and software features:

- Mobile sensor data acquisition based on wireless sensors and handheld PCs
- Accumulation, buffering and (if possible/reasonable) feature extraction mechanisms on mobile device
- Synchronization and immediate data transfer to a server component
- Transfer, storage and management of big amount of data
- Remote analysis and feedback routines for coaches and other experts
- Efficient algorithms for the automated generation of feedback
- Return of notifications to the athletes in almost real time

Usage and Application Scenarios

As mentioned above, possible application scenarios include the training and coaching process in professional and hobby sports like running and cycling. Here it is particularly important to develop effective tools for the monitoring and improvement of the athletes' results by the insertion of instantaneous analysis and notification routines.

In addition, feedback systems are getting more and more popular in fitness and recreation centers as well. Cardio machines like treadmills, stationary bike monitors or cross trainer machines already return information about the participant's heart rate, pace, distance, calories etc. However, regarding the fitness area, one implementation goal in conjunction with the presented research is to build intelligent weight training machines that are capable of sensing the applied force and the instantaneous displacement of the weight and give appropriate feedback. This could result in better assistance for beginners and experienced weight trainers. The high sensitivity of cable force sensors built into training machines seems to facilitate the investigation of the interrelation between cable force and exercising technique. Monitoring cable force and weight displacement allow a more specific resistance training in terms of muscle contraction velocity. Appropriate feedback based on these parameters may assist weight trainers to achieve their personal goals more efficiently.

As another instance, in school sports pupils (in this case representing the "athletes") are often demotivated in doing physical exercises (Weiss, 2004). But exactly sport at young age is believed to have a positive effect in preventing diseases like obesity or diabetes. The insertion of new technology might not only increase the motivation factor but also lead to an ideal workout for the pupils. A computer-aided supervision system can help in optimizing their individual fitness by giving customized instructions and thereby also prevent often occurring frustration but also underload, overstrain or incorrect strain.

Online Training Groups and Communities

Since the framework includes also web-based analysis and feedback tools for coaches but also athletes, other beneficial application fields of the system might be seen not only in the instant access facilities but also conceivable establishment of training groups by feasible comparison opportunities of performance data between registered users. Athletes can view and evaluate their own achievements as well as the ones from their "combatants", possibly resulting in a competitive behavior among them. Such an online competition might boost the athletes' outcomes and lead to the formation of training communities for different sports fields.

Methods

For the purpose of measuring different sport-related parameters (such as biomechanical, physiological data etc.) during training, wireless sensors are attached to the bodies and equipment of the athletes. In addition, they are provided with a handheld PC that captures the measured signals. A mobile application - also called A(thlete)-Client - buffers the data, on the one hand, and immediately transfers it to a remote server component for permanent storage, on the other hand. Distantly located users such as coaches or other specialists but also athletes themselves can then access instantaneously the measured performance data via implemented web applications. Moreover, the so-called E(xpert)-Clients offer routines for analyzing important parameters as well as characteristics and, based thereon, sending crucial notifications to the performing athletes in near real time. The overall concept including the bidirectional interconnection scheme between athlete and expert is pointed out in Figure 2.

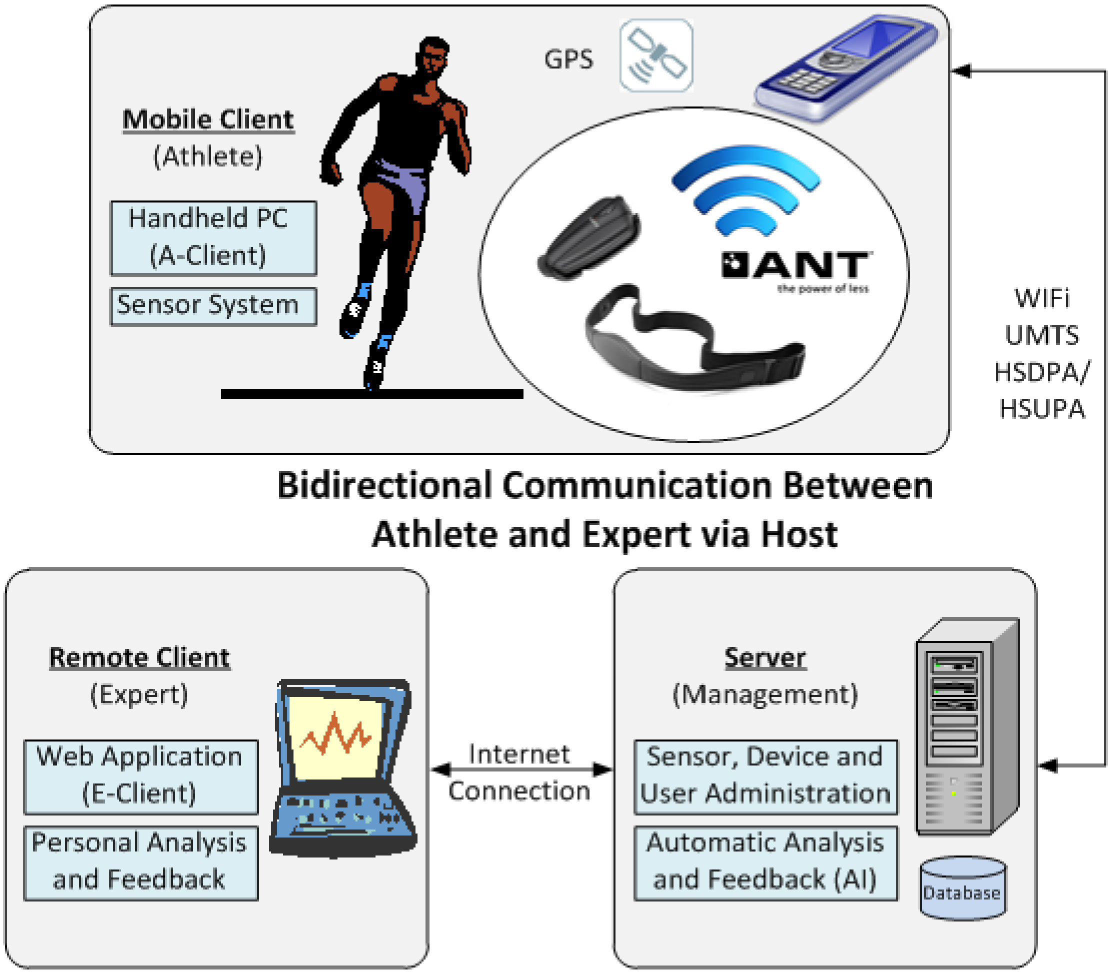

Figure 2. System Architecture.

As shown, the framework can be roughly separated into the 3 subcomponents "Mobile Client", "Server" and "Remote Client". Some of the most significant functional units regarding the mobile coaching system as well as their importance and responsibilities are described in-depth in the following.

Mobile Client

The Mobile Client is represented by the athlete and all the equipment required for the accumulation of sport-specific data (including modern sensors and handheld PCs) but also for the exchange of sensor and feedback information with the server and hence the Remote Client (coach, expert, biomechanist etc.).

Sensor System

Regarding the data acquisition phase, the development of robust sensor systems is of high importance. This requires in particular the implementation of so-called wireless sensor networks (WSNs), Personal Area Networks (PANs) or body sensor networks (BSNs). Current approaches like the ANT™ protocol and its extension ANT+ for sports purposes offer good opportunities for the realization of such sensor networks. The advantages of this technology are seen in its (ANT, 2011):

- Simplicity
- Easy establishment of point-to-point and complex network topologies
- Network flexibility and scalability
- Low power consumption
- Reliable data communication
- Affordable costs
- Unique device identification

As a result of the dissemination, popularity and assertion of the protocol, particularly also in the field of sports applications, the technology is expected to be integrated very soon in the upcoming generation of mobile devices, anticipating ANT to become a common standard such as Bluetooth® in the area of handheld PCs.

In a first instance, a major research goal is to integrate common sensor devices in widely used and easy accessible sports fields like running or cycling. For such purposes, currently the main focus is put on the following ANT+ compatible wireless equipment:

- Heart rate monitor
- Accelerometer
  - Footpod
  - Bikepod
- Neon sensor platform (see below)

The heart rate monitor is one of the most common equipment in the application area of monitoring devices, mainly used as an essential tool for tracking and improving the cardiovascular strength. It usually provides information about the current heart rate (beats-per minute), the time difference between beats (R-R interval) and based thereon the heart rate variability. Meanwhile, there are also specific heart rate monitors which are integrated in the sports equipment like for instance in the women's sports bra. Such fabric solutions are among the most current trends of ubiquitous systems in sports, namely the development of so-called wearable technologies.

The footpod sensor is a relatively small device that is attached to the athlete's foot for the purpose of measuring important parameters such as speed/pace, number of strides and running distance. The measuring method is based on the integration of one or more accelerometers, producing electrical signals with each step taken in running. Similarly, the bikepod monitors the average cycling speed, cadence as well as distance and is usually fixed to the front wheel of the bicycle. The calculated values are determined in accordance to the movement of the bicycle's wheels.

Despite the high number of ANT solutions designed by over 200 ANT+ Alliance Members (ANT+ Alliance Members, 2011), common ANT+ sensors are not always sufficient to measure specific biomechanical or physiological values. Other methods are particularly required when it is of high importance to detect relevant force parameters or weight displacements in sports like fitness. For such purposes, we intend to integrate the so-called NEON sensor platform (Spantec, Linz, Austria), which includes an accelerator, gyroscope and temperature sensor onboard as well as up to 8 analog and digital sensor inputs for further data acquisition equipment such as additional accelerometers, strain gauges, dynamometers, potentiometers or force sensors. The measured signals can be stored locally on a 2 GB microSD card, while the built-in ANT module provides an efficient communication tool with network compatible hardware (Spantec, 2011).

Further training parameters or indicators include for instance the altitude or position of the athlete. An often used method involves the tracking by the Global Positioning System (GPS), which is also integrated in most modern mobile device and therefore easily adaptable to our framework.

Handheld PC

For our purposes, mobile devices like smartphones or MIDs are intended for the reception and further transfer of the obtained values as well as the notification of feedback messages. Hence, the handheld PCs provide an important interconnection between the actual users of the framework - the athlete and the expert.

One specific research task regarding the sensor device connection is the design of homogenous or heterogeneous sensor networks and the processing of sensor values without unneeded power or energy consumption, sensor identification, message overload and data traffic (Fitzek & Rein, 2007). The basis therefore is set up by the underlying sensor network protocol, which has to be adapted and parameterized in regards to the required implementation scopes.

Another crucial point consists in developing convergent implementations based on service-oriented methods for a first reduction of the data volume and extraction of relevant characteristics in terms of information retrieval before actually sending the measured values to the server component.

Finally, regarding the bidirectional data exchange with the host, most of today's mobile devices come with the newest mobile Internet standards such as Wi-Fi or the advanced third generation (3G) technology Evolved High-Speed Packet Access (HSPA+), allowing a wireless web connection with reasonable data rates (up to 84 Mbit/s on the downlink and 22 Mbit/s on the uplink) at almost any place and time. However, one challenge requires the implementation of a stable client-server communication involving the design of appropriate program routines with well-defined message formats for the correct transfer, reception, storage and display of the data packets.

Server and Remote Client

The server is the core component of the system as it is obviously responsible for the storage, administration and management of the sensor, device, user but also feedback information. More crucial, however, it represents the most important link between the performing athlete and the expert by integrating remote analysis and feedback routines.

Analysis and Feedback Routines based on Personal and Automated Procedures

A major intention of the system involves that once the sensor values are transferred to the server component the data has to be accessed instantly by coaches and other specialists. For such purposes the framework should include routines, for example realized by web applications, allowing experts to analyze the current performances by looking at their achievements and send personal feedback messages via the Internet.

Also the automatization of the system plays an important role in our concept in order to be able to find out specific data characteristics of the current performances. Often, the correct interpretation of the values can be made only if the hidden information is discovered. However, due to the often occurring large and complex data structure, such key features are not always directly observable. Consequently, also for experienced coaches and experts it is sometimes hard to analyze the training results correctly and return appropriate instructions to the athletes.

Therefore, a major research aim is to implement automated feedback routines which should detect crucial performance patterns and return appropriate feedback on time, so that for instance underload or overstrain and hence injuries can be avoided. This involves the challenging task of implementing and adapting intelligent algorithms e.g. based on artificial intelligence (AI) methods like expert and knowledge-based systems for the automatic recognition of significant data clusters and computer-based generation of relevant notifications. For such purposes it is essential to establish suitable expert databases for the management of relevant user and training characteristics. This includes for instance the storage and interpretation of the current and past athletes‘ performances as well as the recording of their achievement potentials. In this way, different modeling techniques can be used for the development of meta-models for the determination, analysis and notification of parameter dependent interactions in sports training. Practical solutions include the integration of modeling equations and time series analysis for the design of the interdependency of training potentials and impacts of athletes (Mester & Perl, 2000). The automatic interpretation of the modeled concepts can be then used in order to draw the right conclusion and return machine-aided feedback to the athletes.

Results

Currently our main focus is set on the implementation of a mobile system in the field of school sports. Therefore the application is optimized for the practical use in class (physical exercise) with pupils and teachers as the main users of the framework, correspondingly representing the athletes and experts of the initially presented procedure.

Due to different issues regarding the hardware and constant progress in the fields of sensor, information and communication technologies, several versions have been implemented throughout the development phase. The most significant results of the main user components are presented in the following.

Mobile Client

One of the first approaches regarding the Mobile Client consisted of an Ultra-Mobile PC (Aigo™ P8888W) running Windows XP® and an ANT USB stick for the reception of the sensor values. Due to the relatively big size and further advances in sensor technologies, in a second solution a HTC® Touch 2 with Windows Mobile® 6 in combination with an ANT-enabled microSDIO card (SDA-323, SPECTEC, Taiwan) was used. This approach, however, had reception and thermal limitations in the practical application.

Therefore the current Mobile Client implementation includes an Android-based Samsung® Galaxy 3 smartphone and an individually designed ANT-Bluetooth adapter. The latter - a customized hardware component - embeds an ANT module for the reception of the sensor values, which are forwarded via the Bluetooth element to the mobile device.

User Interface of A-Client

The current design of the user interface of the mobile A-Client program is illustrated in Figure 3. Once the application is started, the pupils have to authenticate themselves by entering their username and password (also required for the access of the web-based E-Client of the framework), which are verified with the server. After a valid login and the selection of the correct sensor data reception adapter (Bluetooth-to-ANT), the application starts looking for the exercise and user dedicated sensors in the surrounding area and displays the identified devices on the screen.

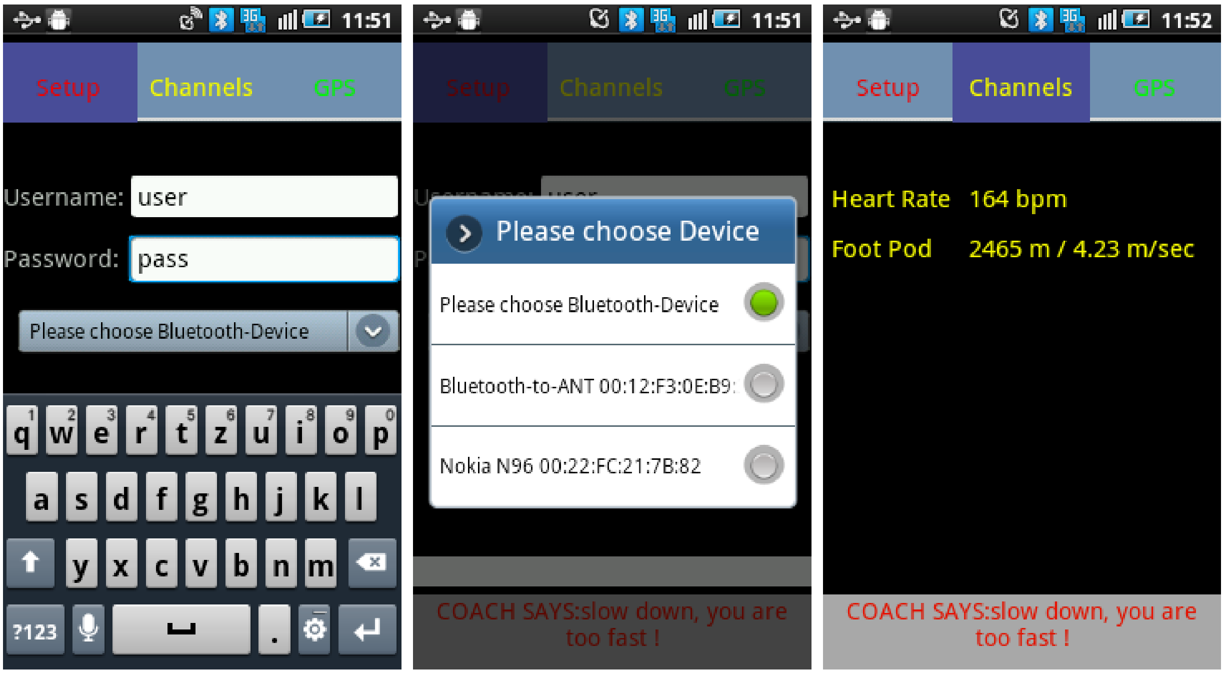

Figure 3. User interface of A-Client.

At that point, the measured signals are processed internally and sent to the host, while the users are provided with their currently achieved parameter values like heart rate, distance, speed etc. The current feedback messages are constantly pulled from the remote server and displayed on the bottom of the mobile program as well as played acoustically to the user. In addition, the application includes a Start/Stop and Pause/Resume button for precise training and time management.

MC Protocol

A core element of the system is the so-called Mobile Coaching (MC)-protocol, which has been implemented in order to be able to configure the ANT equipment, listen to incoming sensor values and communicate with the server. It controls and adjusts the protocol-specific setup (network key, sensor parameters etc.), on the one hand. On the other hand, it comprises special techniques and routines for the authentication and management of the users, their clubs/institutions and the data exchange with the host.

Server Connection

Due to the high importance of low sensor packet loss, the mobile connection to the server was initially based on the Hypertext Transfer Protocol (HTTP) and not on the faster but unreliable

User Datagram Protocol (UDP). Because of the protocol burden, however, meanwhile a socket based Transmission Control Protocol (TCP) approach is realized. Moreover, for better optimization, identification and data reception purposes, in the current framework for each A-Client an individual socket connection is realized.

Remote Client

The Remote Client builds the base for the distant communication between the teachers (experts) and the pupils (athletes). The realization is based on an open source content management system (Joomla!™) and implemented in PHP™ and JavaScript™. The graphical visualization is realized with the XML/SWF Charts tool, which uses dynamic XML data for creating simple but extensive graphs (XML/SWF Charts, 2011).

In a first instance, the implemented web applications include data, presentation, analysis and feedback routines, based on which it is possible to monitor and evaluate the current and already finished performances as well as return crucial notifications to the students. Teachers can follow precisely the progress of the measured data and send remote messages in case of overstrain, underload or any other conspicuousness.

Moreover, the application provides teachers with routines for the management of users and groups as well as training plans, sessions, exercises and the definition of precise workout schedules. Another feature comprises the possibility of assigning sensors to exercises and training sessions to plans (Figure 4).

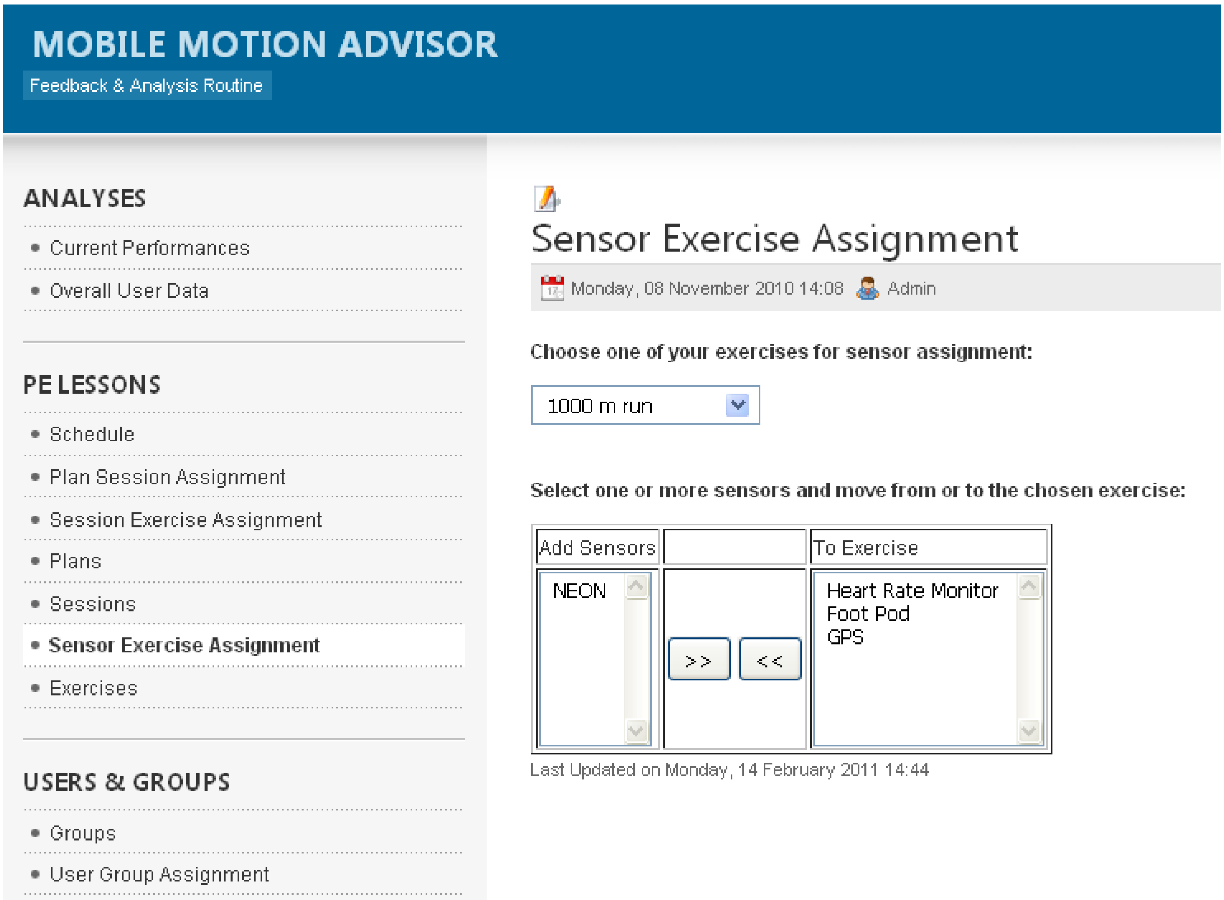

Figure 4. User interface of E-Client.

Further Work and Outlook

In regard to the school project, the next steps of the development involve the very significant testing and evaluation phases of the framework. For such purposes, the mobile system will be applied under real conditions with pupils. During physical exercise, students are equipped with the hardware equipment, while their teacher can have a prompt control over all the data of the performing kids using another mobile device like a tablet computer (e.g. Samsung® Galaxy Tab). The overall assessment will be conducted by means of an empirical study based on questionnaires.

Discussion

The initially described Hawk-Eye system as an area of application shows the high potentials of pervasive computing methods in the field of sports competition. Nevertheless, the insertion of such equipment is still heavily contested, particularly in tennis by those players that criticize the accuracy of the Hawk-Eye (within 3mm) as well as its high costs. Also in soccer, as another instance, such a technological aid has not been introduced yet due to different points of criticism and issues. Hence, the adjudication in sports based on ubiquitous technologies is still not completely accepted, but with the permanent advances in applied informatics also the appreciation might grow and it seems to be only a question of time until computer-based assisting methods will take hold in sports competitions.

Regarding coaching and training, ubiquitous technologies are in high demand and increasing usage as they can be easily implemented to support effectively athletes and their coaches, on the one hand. Concerning the data acquisition phase, today's advanced sensor, information and communication technologies facilitate compact and convenient opportunities to obtain physical, physiological or position data. The use of modern wireless devices based on advanced sensor network protocols allow a less interfering way of measuring different kind of sport-specific parameters during the training units. Up-to-date handheld PCs can be then used for the reception, collection and further transfer as well as analysis of the obtained data.

Differences to Other Training Systems

The proposed system suggests an innovative server-based approach for the analyses of near real-time data in sports. Moreover, the system includes novel feedback modules for the immediate return of important notifications to the athletes. Based on the measured parameters, such feedback information can be sent individually by coaches and other experts from remote locations, on the one hand. In addition, a major novelty is also the automatization of the feedback generation routine by the integration of intelligent methods.

Obviously, such remote intervention possibilities bring many other positive consequences. Based on the possible distant communication, coaches do not always have to accompany their athletes, which might involve lower costs as well as expertise analyses by different specialists on the performances at the same time. Another big advantage arising by the integration of a centralized host machine involves the option of analyzing not only the current training result but also in combination with previous performance outcomes.

Requirements, Limitations and Complications Regarding the Design of Pervasive Training and Coaching Methods

Obviously, a major requirement for the design of feasible training and coaching systems involve that the newest pervasive technologies and standards are integrated in the development as soon as they become available. Regarding mobile approaches, it is for example significant to insert novel products in order to guarantee a power and energy efficient implementation of embedded solutions.

Despite the constant progress in information and communication technologies, a couple of considerations concerning the realization of the required hardware and software tools have to be made as well. In the course of our research, we have experienced several practical issues and complications.

In a first instance, the mobility communication regarding the use of handheld PCs is one limitation factor, particularly when sending huge amounts of data such as dynamic movement parameters in fitness. In such cases it is essential to implement accurate buffering and synchronization methods for the purpose of transferring the data as soon as possible. This kind of temporary data storage is an essential and effective approach in these application scenarios since it is sometimes not advisable or possible to receive the feedback information immediately but for example just after the completion of a set. In the near future, however, it is also expected that with the establishment of advanced protocols (4G - fourth generation) such as WiMAX (Worldwide Interoperability for Microwave Access) the speed of wireless mobility communication will continue growing.

As another instance, we have experienced temperature problems (failure at higher degrees) as well as such regarding the range with the initially used ANT microSDIO card. The reception might have been limited due to the fact that the card is placed inside the mobile device and is therefore close to other electronic components like the battery. Because of such complications, an individually designed adapter for the communication between sensors and mobile device has been developed. Such additional equipments, however, have the disadvantage that they might increase the interference with the athletes.

Regarding positioning systems, it has to be kept in mind that approaches like GPS are often limited or sometimes completely unavailable (e.g. indoor conditions). First of all, due to the satellite-based approach, the signal is highly influenced by weather conditions. Secondly, the reception might be interfered by objects (e.g. trees) or other electronics in the surrounding area. Therefore, mountain bikers might experience difficulties in receiving a good signal in forest areas, while performing athletes in sports halls won't have any GPS reception available. For such purposes, accurate indoor positioning mechanisms have to be integrated instead.

Conclusion

The current paper presents the implementation of a mobile coaching system based on the integration of ubiquitous technologies and procedures with the intention of supporting athletes, coaches and experts as well as pupils and teachers in their workout process. The broad possibilities, capabilities and diversity of pervasive equipment such as mobile devices and sensor technologies enable effective facilities for the development of assisting, monitoring, enhancing, regenerative and preventive training applications. Ubiquitous approaches for improving the training and competition performances of athletes but also for preventive purposes have evolved a lot in the last couple of years and are of high importance today. In this spirit, it can be concluded that the illustrated framework builds a very future-oriented basis for athletes and experts in means of assistance, mentoring, support and prevention. Hence, further research should be carried out in order to ensure the progress and establishment of continuatively effective training opportunities.

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Software Package for Assessment of Visual Perception and Anticipation Ability in Combat Sport

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Abstract

The purpose of this paper is to introduce equipment for estimation and training of anticipation performance in the combat sport karate. This equipment comprises a measuring station and a PC-software, which contains a database of videos and athletes, several tests and analysis routines and reports for the coach.

KEYWORDS: ANTICIPATION, KARATE, TEST, SOFTWARE, VIDEO BASED MEASURING STATION

Introduction

In sport science anticipation is understood as the presumption of an action, an action effect or outer dynamic changing of environmental conditions (Munzert, 2003).

Due to the fact that the athlete has to anticipate the opponent's manifold actions in order to react suitable under time pressure, anticipation is exceedingly important in martial arts. It is important that the reaction to the attack is executed as soon as possible (best at the beginning of the attack) by means of an effective counterattack or an avoiding movement. Figure 1 demonstrates the time relations between attack and reaction.

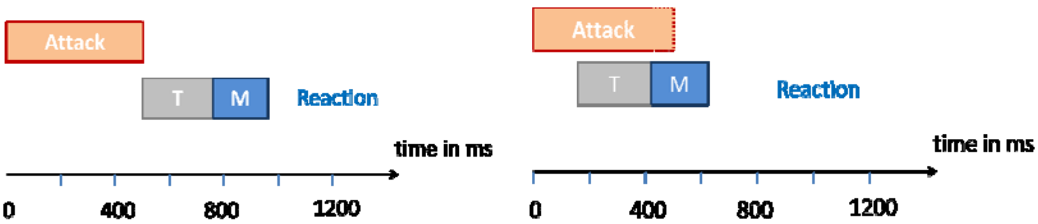


Figure 1. Schematic diagram of the temporal relations between attack and reaction (T – reaction time, M – movement time). Left: the athlete recognizes the attack to late which results in a delayed reaction, right: the athlete recognizes the attack early and reacts before the end of the attack.

Accordingly it can be assumed that experts are able to conclude the intended action through the opponent's body posture (s. Bideau, Multon, Kulpa, Fradet & Arnaldi, 2004). Contrary to that the athlete does not want his opponent to anticipate his action by means of tricks (e.g. feints in boxing, Hussein, 2004). The purpose of the appropriate reaction is to influence the situation for the athlete's own benefit (Weigelt & Steggemann, 2010). Anticipation not only has a big relevance in martial arts, but also in sports games. For instance, the handball keeper has to identify the throwing parable from the posture of the thrower in order to counter favourably. Essential researches about eye movements or visual strategies are known by Roth & Schorer

(2007). Spatial and temporal occlusion tasks are being used to identify which information at which time is observed by the athlete (Albernethy & Zawi, 2007; Roth, Schorer, Höner & Forstner, 2006). The importance of the distinction between early and late cues can be found in the literature (Froese & Plessner, 2011). Nevertheless the results are not clear due to the fact that the used term reaction time seems to be prob-lematic, whereas the stimulus and it's time point are unknown. The normally used term reaction time would appear to be problematic, because the stimulus and its time point are unknown. However the term "reaction time" will be used in this paper.

In consideration of the comparison between squash experts and novices Abernethy (1990) found out that visual search strategies are not crucial for beginners and that they are unable to employ the information. Many studies of eye movements in relation to a specific stimulus show that experts exhibit fewer fixations in number but longer in time than novices (Mann, Williams, Ward & Janelle, 2007).

Results show that a sport specific video, based on a tactical training of perception, leads to clear improvements of the reaction time without an increasing of the error rate (cf. Cañal-Bruland, Hagemann & Strauß, 2005). There are few studies, as from Williams & Elliott (1999), which record visual search strategies with the help of helmet cameras in the field of karate sport. Mori, Ohtani & Imanaka (2002) researched reaction times of karatekas to sports specific and unspecific stimuli at a computer monitor.

The aim of this paper is the introduction of video based test equipment which allows the quantification and the training of anticipation by means of both a relative practical rele-vant measuring station and a PC-software. The procedure is demonstrated using the example of karate-kumite. It is well-known that for the kumite competition the reaction to the attack of the opponent at a temporal time point with adequate block techniques and counterattacks or their combinations is very important.

Methods

The procedure of the test's execution is described as follows. The test is subdivided into a Practice- Test and a PC- Test. In the first instance the trainer is asked to choose videos from a database of karate attacks, which are relevant to athletes, and to determine their chronological order. Thereafter he has to define the point of time at which the attack can be identified. The use of own records is possible, too. In the Practice Test the athlete is shown the life-size videos on which he has to react adequately and with qualified karate techniques. During the Practice-Test life-size videos were shown to the athlete. He is asked to react adequately with qualified karate techniques. The whole scenario is recorded by a video camera. In the context of the PC-Tests the videos with the same attacks were shown to the athlete in real time (PC-Realtime-Test: PCR-Test) and in slow motion (PC-Slow Motion-Test: PCSM-Test). The athlete has the task to react by key press (Figure 2 shows the screenshot).

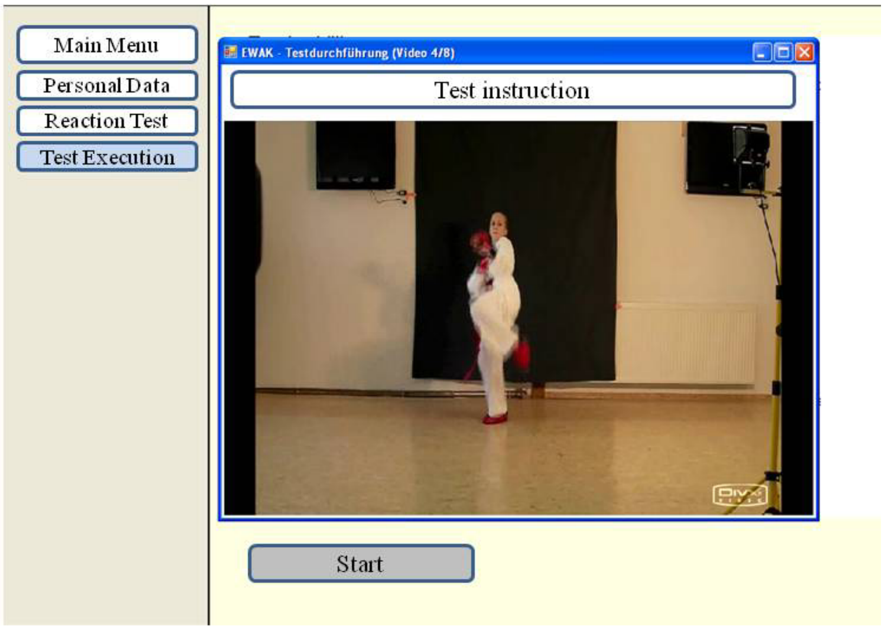


Figure 2. Screenshot for the PC-Test in real time and in slow motion. Athlete reacts by key press.

Furthermore, the athlete is requested to press a key and to specify the identifications for the attack: changes of the posture or movement of body segments (Figure 3 shows the screenshot). In addition a simple visual reaction test could be carried out. The data were stored in a database and is available to the coach. Now he has the possibility to evaluate the Practice-Test as well as the PC-Tests. Figure 4 shows a screenshot for the evaluating of the Practice-Test in the trainer mode.

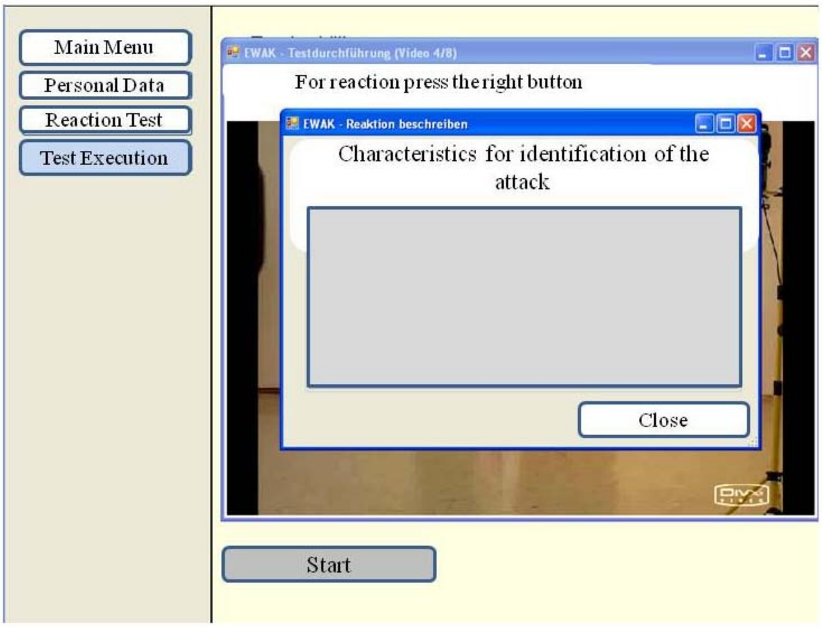


Figure 3. Screenshot for the PC-Test to describe the characteristics of the attack.

Figure 4. Screenshot of the trainer mode to evaluate the Practice-Test.

The coach rated the time point of the reaction by means of a ranking scale (from -1 to +3). "-1" means no reaction and "+3" the optimal time point of the reaction in the Practice-Test as well as in the PC-Tests. Furthermore, if the reaction technique was adequate the appropriation of the reaction technique was estimated. The results were displayed with help of net diagrams. In this way both an individual and a group specific analysis were possible.

Within the framework of a pilot study the total test equipment was checked. 16 male (5 x Dan, age: 18.6 ± 5.7, years of training: 7.2 ± 3.3, all athletes are squads) and 9 female karatekas (3 x Dan, age: 18.3 ± 4.3, years of training: 8.8 ± 3.4, 7 athletes are squads) with national and international experiences in competition participated in this study. The following attacks and their combinations (partially executed by different athletes) were selected by the coach:

- Gyaku-Zuki (left and right),
- Gyaku-Zuki over run,
- Mawashi-Geri,
- Ura-Mawashi-Geri,
- Kizami-Zuki / Mawashi-Geri (rear leg).

The selection of the attacks was carried out corresponding to the relevance in competition. The Gyaku-Zuki for example is the most frequently executed technique. It is a reverse push that means that the left or the right leg is moved forward and the reverse arm executes the fist push (Nakayama, 1981). The Gyaku-Zuki is executed in several variations (for instance: over run). The other arm technique (Kizami-Zuki) is done by snapping the leading fist forward in a jab without moving the front leg. It is often used as a push movement in combination with the Gyaku-Zuki or Mawashi-Geri. Most athletes use a trick such as the Kizami-Zuki immediately before attack. The Mawashi-Geri is a "roundhouse kick", which can be executed with the front and the back leg. The Ura-Mawashi-Geri is similar to the Mawashi-Geri with the exception that the target is on the reverse side of body. Both kicks are relevant in competition, because their rating is higher than a hit. Biomechanical analyses of these techniques were done by Witte & Emmermacher (2009). Additionally it should be shown that the reaction is dependent on the athlete executing the attack (subject 1, 2 or 3).

Results and Discussion

Figures 5 and 6 show the mean assessments for the reaction time of the athlete for the Practice-Test and the both PC-Tests carried out by the coach.

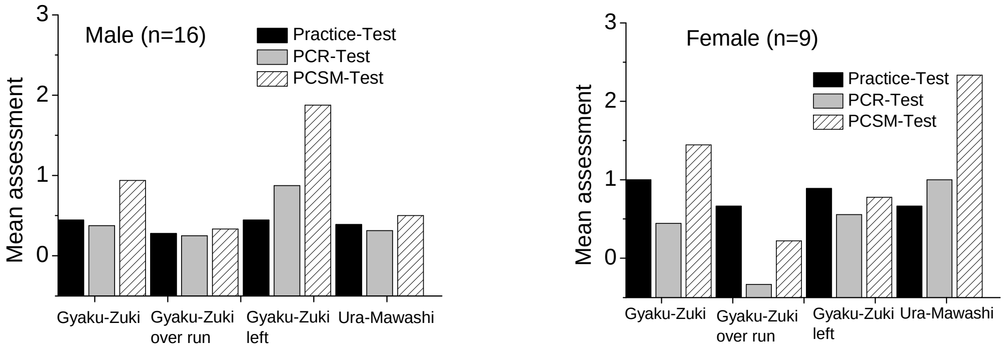


Figure 5. Mean assessments of the reaction time for different executions of the Gyaku-Zuki and the Ura-Mawashi-Geri.

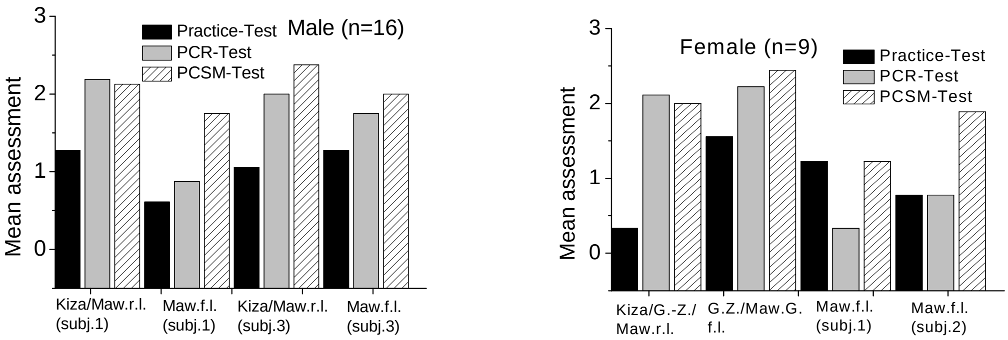


Figure 6. Mean assessments of the reaction time for the Mawashi-Geri (front leg) and two technique combinations.

At first sight it becomes apparent that the techniques were anticipated differently. Generally it can be found that kicks and technique combinations were better anticipated than the fist hit Gyaku-Zuki. This is a problem in the practice of competition, because the Gyaku-Zuki and its variants of executions are the most frequently used techniques. The comparison of the separated tests among each other exhibits only a few significant differences (see Table 1 and Table 2).

The validity of the Practice-Test was checked by means of a small study (n = 6, number of the same techniques for each athlete: 8) based on the absolute reaction times. The subjects were asked to react to the attacks under real condition and to the attacks under video conditions (Practice-Test) which were in changed order. With help of a paired t-test non significant differences were found (Real-Test: 195ms±95ms, Practice-Test: 300ms±95ms, $p = 0.369$). The trend to higher values of reaction times for the Practice-Test is caused by two reasons: two-dimensionality of the video and unfamiliar test conditions.

Table 1. Mean comparison test between the assessments of the single tests for the male subjects, Wilcoxon signed-rank Test, r.l. – rear leg, f.l. – front leg.

Technique	**Practice-Test vs. PCR-Test**	**Practice-Test vs. PCSM-Test**	**PCR-Test vs. PCSM-Test**
Gyaku-Zuki	0.94	0.262	0.012
Gyaku-Zuki over run	0.81	0.98	1.00
Gyaku-Zuki (left)	0.035	0.001	0.002
Ura-Mawashi (rear leg)	0.034	0.023	0.452
Kiza/Maw.(r.l.) subj.1	0.067	0.048	0.187
Mawashi (f.l.) subj.1	0.41	0.022	0.001
Kiza/Maw.(r.l.) subj.3	0.44	0.177	0.406
Mawashi (f.l.) subj.3	0.014	0.023	1.00

Table 2. Mean comparison test between the assessments of the single tests for the female subjects, Wilcoxon signed-rank Test, $p<0.05$, r.l. – rear leg, f.l. – front leg.

Technique	**Practice-Test vs. PCR-Test**	**Practice-Test vs. PCSM-Test**	**PCR-Test vs. PCSM-Test**
Gyaku-Zuki	0.45	0.73	0.03
Gyaku-Zuki over run	0.11	0.11	0.25
Gyaku-Zuki (left)	0.59	1.00	0.50
Ura-Mawashi (rear leg)	0.625	0.016	0.031
Kiza/Gyaku-Zuki/Maw.(r.l.)	0.016	0.062	1.00
Gyaku-Zuki/Maw.(f.l.)	0.176	0.078	0.50
Mawashi (f.l.) subj.1	0.078	1.00	0.062
Mawashi (f.l.) subj.2	1.00	0.016	0.008

In Figures 7 and 8 the mean assessment of the reaction quality is given. At this the coach decided between adequate and non- adequate techniques in relation to the attack. For all subjects the reaction depends on the attacked karateka. The reason therefore is that individual executions of the techniques can be recognized differently. It can be noted that the male athletes show slow reactions with the Gyaku-Zuki and the Ura-Mawashi-Geri, whereas the females react slowest with the Kizami / Mawashi-Geri.

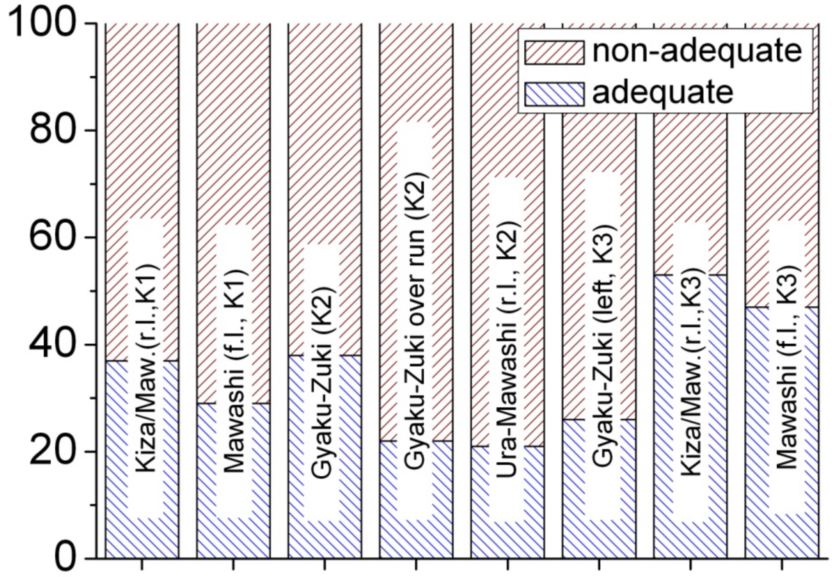


Figure 7. Percental number of non-adequate and adequate reactions to the special attacks (total number of the attacks was set on 100) for all male karatekas. The assessments of the quality of the reaction were done by the coach.

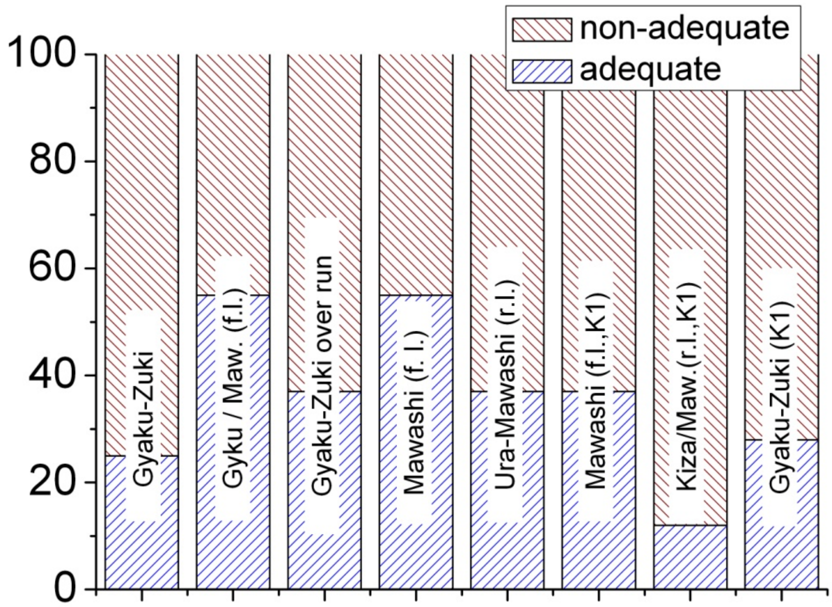


Figure 8. Percental number of non-adequate and adequate reactions to the special attacks (total number of the attacks was set on 100) for all female karatekas. The assessments of the quality of the reaction were done by the coach.

Because the athletes have different levels of performance and are of different age and in order to optimize the training program the coach's main interests are the results of every single athlete. In the menu item "analysis" in the coach mode of the software package all data can be exported into a table. For instance, by the software "Excel" net diagrams can be designed. Figures 9 and 10 show the net diagrams of all tests with test repetition using the example of a male and a female subject. The male subject (23 years, 1.72 m, 60 kg, 2nd Dan, all-state first team athlete, 16 years training of karate) with much experience in international competitions; the female athlete (19 years, 1.72 m, 60 kg, 4th Kyu, B-squad (federal state), 12 years of karate training) had experience in national competitions.

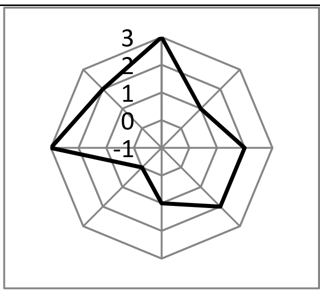
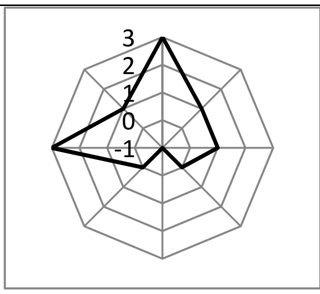
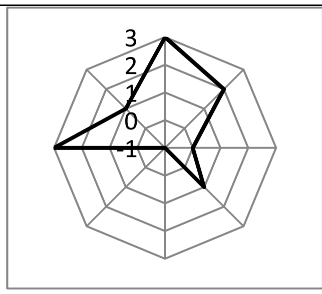
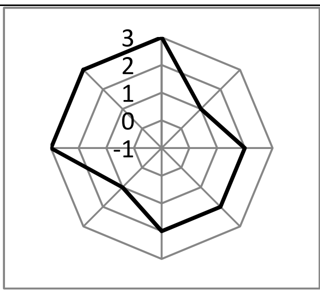
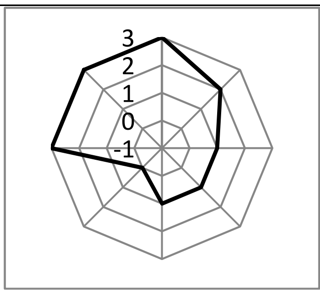
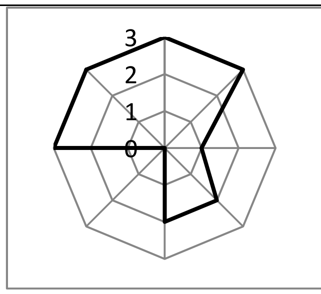
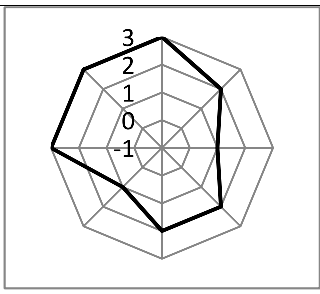
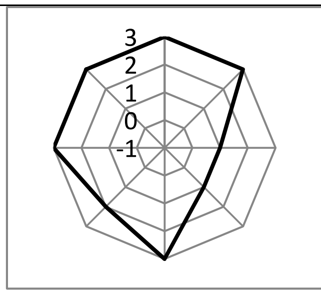
Test	Practice-Test	PCR-Test	PCSM-Test
1			
2a			
2b			

Figure 9. Net diagrams of assessments of the reaction time for various karate techniques and combinations for a male athlete. From top in clockwise direction: Kizami-Zuki/Mawashi-Geri (rear leg), Mawashi-Geri (front leg, subj. 1), Gyaku-Zuki, Gyaku-Zuki over run, Ura-Mawashi-Geri, Gyaku-Zuki (left), Kizami-Zuki/Mawashi (rear leg, subj.1), Kizami-Zuki/Mawashi (rear leg, subj.3), Mawashi-Geri (front leg, subj. 2).

For both subjects it can be concluded that the reaction times improve for the Practice-Test at repetition (compare test 2a with test 2b). The reaction techniques of the male athlete were all suitable, whereas for the female athlet they were only noted as adequate for the combination Kizami-Zuki / Gyaku-Zuki / Mawashi-Geri. Improvements of reaction times for both PC-Tests were found. After an immediate repetition (Test 2b) of both PC-Tests a further improvement is remarkable. Due to the fact that the results of the other five subjects, who executed the repetition test, it can be assumed that anticipation is trainable. Nevertheless the difference is not significant in every case (see Table 3).

Table 3: Mean assessments of the reaction time, Test 1: first test, Test 2a: second test, Test 2b: repetition of the second, n = 6.

	Test 1	**Test 2a**	**Test 2b**
Practice-Test	0.83 ± 0.77	1.00 ± 1.20	
PCR-Test	1.00 ± 1.36	1.36 ± 1.35	1.52 ± 1.38
PCSM-Test	1.39 ± 1.41	1.96 ± 1.31	2.25 ± 1.16

Only for the PCSM-Test between Test 2a and Test 2b a significant difference was found (Wilcoxon signed-rank Test, $p<0.5$). A learn effect (anticipation) can cause the better results of the second test. The detailed analysis of the performance of the male athlete (Figure 8) shows that the Gyaku-Zuki and its variants, as well as the combinations with other techniques, were anticipated worst. Because the other athletes exhibit the same phenomenon this technique should be a main focus in the practice of kumite training. Certainly difficulties arise by reason of the fact that the Gyaku-Zuki is one of the fastest karate techniques (Emmermacher, Witte and Hofmann, 2005).

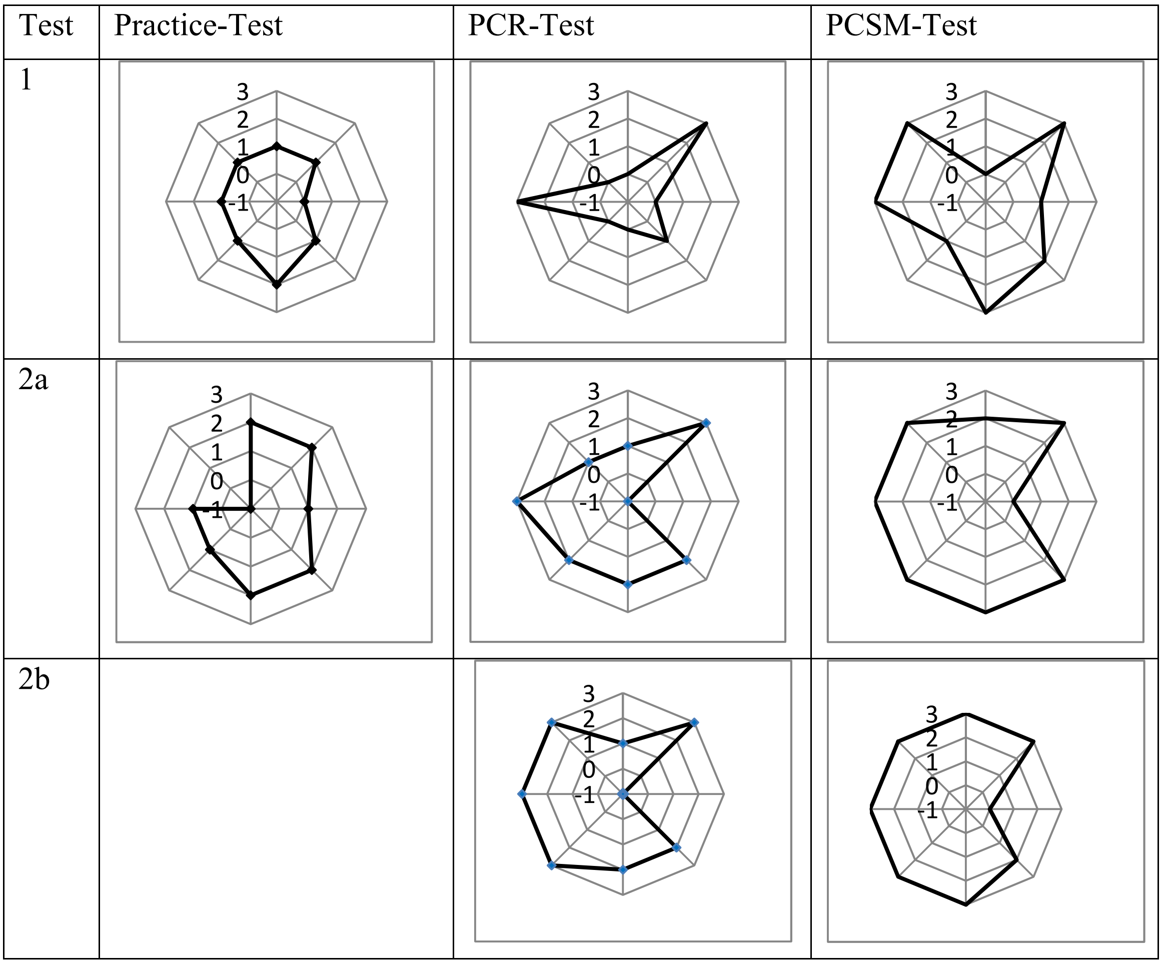


Figure 10. Net diagrams of assessments of the reaction time for various karate techniques and combinations for a female athlete. From top in clockwise direction: Gyaku-Zuki (left), Gyaku-Zuki/Mawashi (front leg), Gyaku-Zuki over run, Mawashi-Geri (front leg, subj. 1), Ura-Mawashi-Geri (rear leg), Mawashi-Geri (front leg, subj. 2), Kizami-Zuki/Gyaku-Zuki/Mawashi (rear leg, subj.1), Gyaku-Zuki.

Remarkably are the answers of the subjects to the question regarding which sign and whereby they recognize the attack. Both subjects indicate specific movements of arms, shoulder and upper part of the body. The analysis of the other subjects yields that athletes with fewer experiences in competition concentrate on the arm movements or they are not able to describe variations of the body posture. In contrast, athletes with long lasting experiences recognize changes of the total body posture and mimic or they can identify tricks.

Conclusion

The presented video based test equipment contains a practical test and two PC-tests in real time and slow motion. The equipment's design includes all steps/features: video selection, data base with subjects, single tests with analysis.

The current version respects the experiences and wishes of the coaches. Future researches with this equipment should provide information whether the movement of the opponent is observed more aware by the athlete. Furthermore a verification of an improvement of the competition performance by this equipment is necessary. Currently a feasibility study examines the application of techniques of virtual reality to improve the three-dimensional visual perception of the opponent and his attacks (aided by Bundesinstitut für Sportwissenschaft, Germany, IIA1-071504/10). Figure 11 shows the experimental setup in a CAVE. The reaction times of the athletes were recorded with high speed cameras triggered with acceleration and EMG sensors.

Figure 11. Athlete reacts on the attack of a virtual opponent in a cave (Virtual Development and Training Centre VDTC of the Fraunhofer Institute for Factory Operation and Automation IFF Magdeburg, Germany).

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Recognition of Individual Kinematic Patterns during Walking and Running – A Comparison of Artificial Neural Networks and Support Vector Machines

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Abstract

Modeling of complex relations concerning the analysis of patterns of human walking and running in the past years was realized using different methods of soft-computing. Looking at the classification of individual movement patterns optimized model approaches seem to lead to an advancement regarding classification rates. In the present analyses kinematic data of eight male competitive athletes (middle- and long-term running) were collected while walking respectively running on a treadmill at three different velocities. The segmented and modeled data were used to train an Artificial Neural Network (ANN) and a Support Vector Machine (SVM) in order to compare the classification rates of the models regarding the identification of subjects due to their kinematic patterns. As expected the optimized SVM separated the data over all velocities more precisely and classification rates of 100% could be achieved concerning the identification of subjects (ANN 94%-95.5%). Regarding the identification of individuals with models that were trained with data from different velocities the SVM could still achieve a classification rate of 98.6% (ANN 94%). Due to the implemented optimization in data separation classification of unknown data with the SVM leads to a higher rate of classification.

KEYWORDS: PATTERN RECOGNITION, TREADMILL SURVEY, ARTIFICIAL NEURAL NETWORK, SUPPORT VECTOR MACHINES, KINEMATIC ANALYSIS

Introduction

Regarding the last years modelling of multidimensional relations of kinematic patterns of physical activities has been successfully realized using soft-computing methods. (Perl, 2007; Schöllhorn et al., 2002). Primarily Artificial Neural Networks (ANN) were used to analyze patterns which in context of time and space are exposed to dynamic changes. ANNs model prevailing and future conditions considering the history of the biological system and evaluate conditions in context of the multidimensional changes taking place. Particularly with regard to the discrimination of individual motion patterns during physical activity optimized model approaches for pattern recognition seem to lead to more accurate results than conventional ANNs. The presented work focuses on to the analyses of individual motion patterns using the example of a treadmill survey with Support Vector Machines (Schölkopf & Smola, 2002) and challenges their suitability to classify patterns in comparison to Artificial Neural Networks.

Methods

Data collection methodology

During a treadmill survey kinematic data were collected of eight subjects walking respectively running at speeds of 1.2m/s, 3.0m/s and 4.0m/s. Each subject completed three trials on each speed. To ensure that walking patterns of the subjects were not falsified by adaptation processes to walking under treadmill conditions and/or the predetermined speed the first trial of every new condition was defined as familiarization phase and was not included in the analyzes. The remaining trials were used for training and recognition. The length of the sampling interval was long enough that for every subject data of at least 24 double stance phases could be collected for each speed.

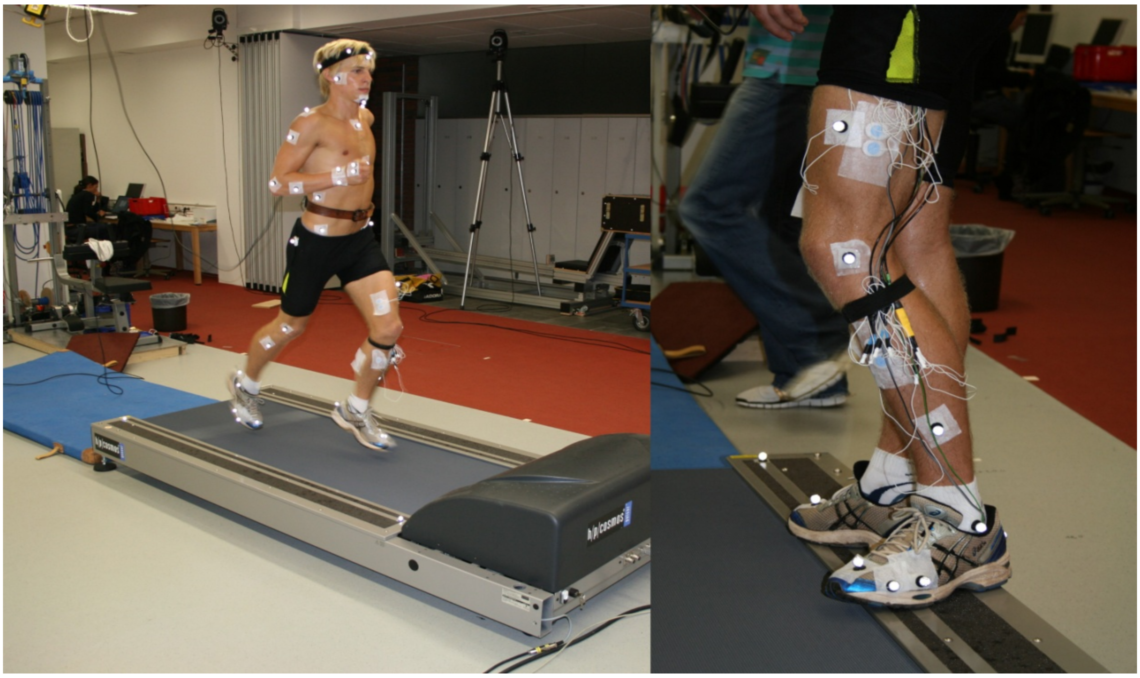

Figure 1. Experimental setup.

Kinematic data collection: Kinematic data of eight competitive athletes practising middle- or long-distance running were collected with a VICON MX-System including ten cameras at a sampling rate of 250Hz. Reflective markers at a diameter of 14mm were attached to the subjects according to the VICON PluginGait Markerset. In addition supplementary markers were attached which were used for filling gaps in the trajectories of markers of PluginGait Markerset. EMG-Data was collected with a wired system and recorded with the VICON a/d-converter synchronously. In addition a video signal was recorded synchronously at a frequency of 50 Hz.

Electromyographic data collection: The recording of muscle activity was realized with a wired EMG-System at a frequency of 1kHz. For the analysis of muscle activity during walking and running only muscles of the lower extremities came into consideration. Electrodes were attached to M. Gastrocnemius lateralis, M. Soleus, M. Bizeps femoris, M. Tibialis, M. Vastus medialis and M. Vastus lateralis of the dominant leg.

Artificial Neural Networks

Artificial Neural Networks (ANN) are established methods regarding the classification of physical activity. Due to multi dimensionality of the data to be processed the training of the networks can be reduced to the solving of non-linear optimization problems. Therefore the parameters to be optimized consist of the weights of neural links which are initially approached to a solution by an estimation to facilitate a precise classification of the training data. The capacity of Artificial Neural Networks to generalize is limited. Due to the non-linear optimization it is not safely guaranteed that the determined estimation of network parameters show a globally or only a locally optimized solution .Furthermore the solution of the problem depends on the initialization of neural weights which in result does not lead to a distinct solution.

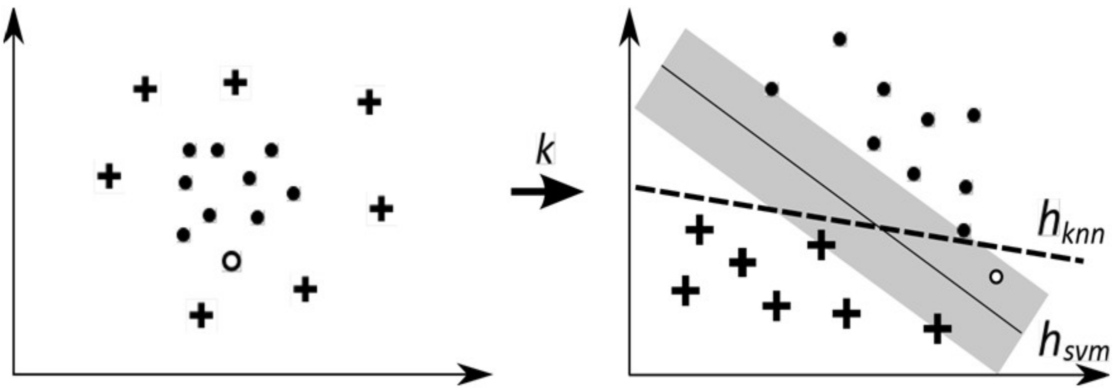

Figure 2. Non-linear data of class 1 (circle), 2 (cross) and testing date of class 1 (left). In feature space represented data with *k*, subdivided linear by hyperplane generated by SVM (h_{svm}) and KNN (h_{knn}). Testing date represented by hole.

Support Vector Machines

The Support Vector Machine (SVM) is a method for classification used mainly in machine learning for primarily separating linear data. Non-linear data are represented in a high dimensional space (feature space) using a function of representation k – the kernel function. In the feature space data can be again linearily separated by a hyperplane (Figure 2). Training data located next to the hyperplane therefore present the support vectors. In addition to the optimization of parameters of the plane leading to a valid result for the present training data a maximization of the distance between support vectors and the plane is implanted. Due to the large number of variables and restrictions of the generated optimization problem Langrange-Multipliers must be established leading to a quadratic problem. As shown in Figure 2 the additional maximisation of the distance causes a distinct optimal separation of the data thus resulting in a higher ability of generalization of the SVM.

Stochastic modelling

The training and recognition was realized on Data of diverse trials. To be capable to train models for classification of walking and running with Artificial Neural Networks and Support Vector Machines, a certain number of key frames representing discriminatory changes in velocity were determined from the segmented data. By this means, the amount of training data is reduced and time invariance is given. We experienced that 3 frames for each segment are sufficient to form a feature vector which provides enough information for accurate classification. These vectors were put together to one training dataset for each of the four types of segments. For the approach with ANNs the library Fast Artificial Neural Network (FANN) (Nissen, 2003) was integrated permitting an efficient construction and fast training of ANN for binary classification. Based on the assumption that a walking movement consists of four segments, for the realisation of the multiclass-classifier 1-vs-all models were trained and combined. Since our main focus lies on the classification of a movement whereas the structure of the segments is considered to be known and, hence, does not need to be learned, a 1-vs-all classifier features the advantages of a more efficient training process regarding run-time and the amount of training data. The structure of the ANN-Classifier is shown in Figure 3.

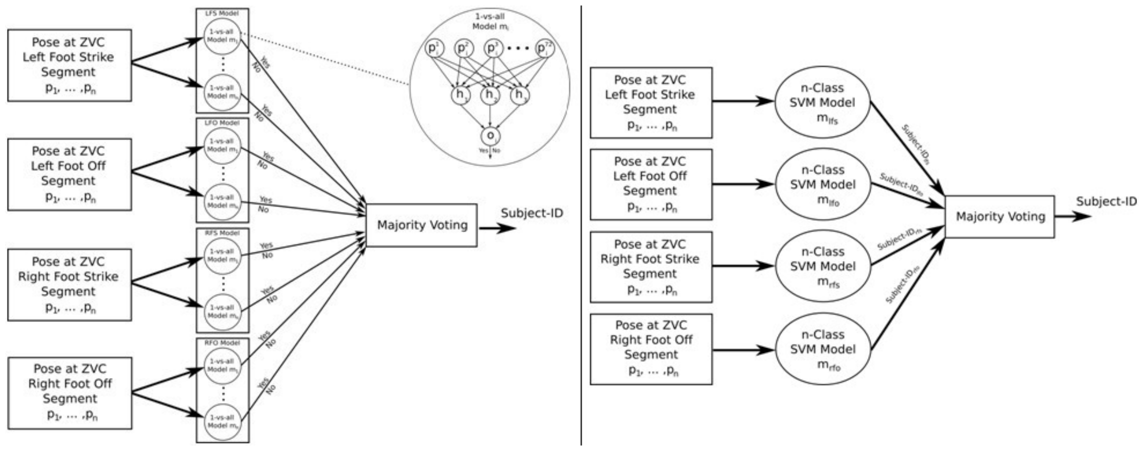

Figure 3. Structure of NN-classifier and SVM-classifier for walking and running. p_n represents a feature vector for the demonstration n.

Concerning the SVM a multiclass-SVM was integrated. The SVM was trained using a Gaussian radial basis function kernel. For classifying a movement consisting of four segments for each segment one model was trained. The results of classification of each model were combined in a majority voting (Figure 3). For the evaluation of the quality of classification of both methods four sets of training data of about 885 Segments for each type of segment out of 1131 (about 222 for each subject) walking/running cycles were generated for three different velocities. The remaining data were used for evaluation.

Results and Discussion

Depending on the tested velocity using the ANN between 94% and 95.5% of the subjects could be identified. However using the SVM a rate of classification of 100% over all velocities could be achieved. Identifying individual patterns at a velocity of 4m/s with models being trained with data of 1.2m/s and 3m/s the SVM achieved 98.6% compared to the ANN with a 94% classification rate. By continuously reducing the amount of training data it could further be shown that the quality of the ANN did not increase significantly with training instances larger than 96 and 128 instances for the SVM. In addition to the classification of subjects it was evaluated whether the velocity of walking/running of the subject could be identified. According to this scenario the ANN showed a classification rate of 90.2% in comparison to the SVM achieving 95% of classification. Whereas the ANN showed tendencies to overfitting the SVM possesses a greater ability for generalization. Due to the implemented optimization the best possible solution for the separation of datasets via a hyperplane is ensured. This leads to a higher rate of classification particularly for unknown data.

Table 1: NN and SVM comparison of rate of classification. Column 1: Training and test over all velocities. Column 2, 3, 4: Training and test with stated velocity. Column 5: Training with 1.2 und 3.0 m/s and test with 4.0 m/s.

	Subjects at 1.2, 3.0, 4.0 m/s	Subjects at 1.2 m/s	Subjects at 3.0 m/s	Subjects at 4.0 m/s	Subjects at 4.0 m/s with training of 1.2, 3.0 m/s
NN	94 %	95 %	95,3 %	95,5 %	94 %
SVM	100 %	100 %	100 %	100 %	98,6 %

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An eLearning Module for the Biomechanical Analysis of Motor Performance in Sports – A Learning Tool for Academic Teaching

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Abstract

A teaching approach is introduced to supplement regular classroom teaching in elementary physics through an eLearning module. The approach aims to promote a multimodal learning in the field of sports biomechanics based on the benefits of a multimedial learning environment. This paper outlines the basic structure and a first step towards an evaluation of the given eLearning units when being used as an add-on to a university seminar on Biomechanics in Sports. The results of the evaluation indicate that eLearning material should be used in self-directed learning settings only with learners having a precise guideline on exactly what to do and how long to do it.

KEYWORDS: ELEARNING, BIOMECHANICS, MULTIMODAL LEARNING

Introduction

Understanding movements in sports is considered to be a key issue for the academic training of physical education (PE) teachers. However, particular teaching constraints must be accounted for when teaching biomechanical principles of motor performance in sports at a college or university level. In particular, differences in the learning prerequisites among students are often observed that might originate from individual objections against science subjects in general as well as previous biomechanical teaching units at a high-school level that some students attended while others did not.

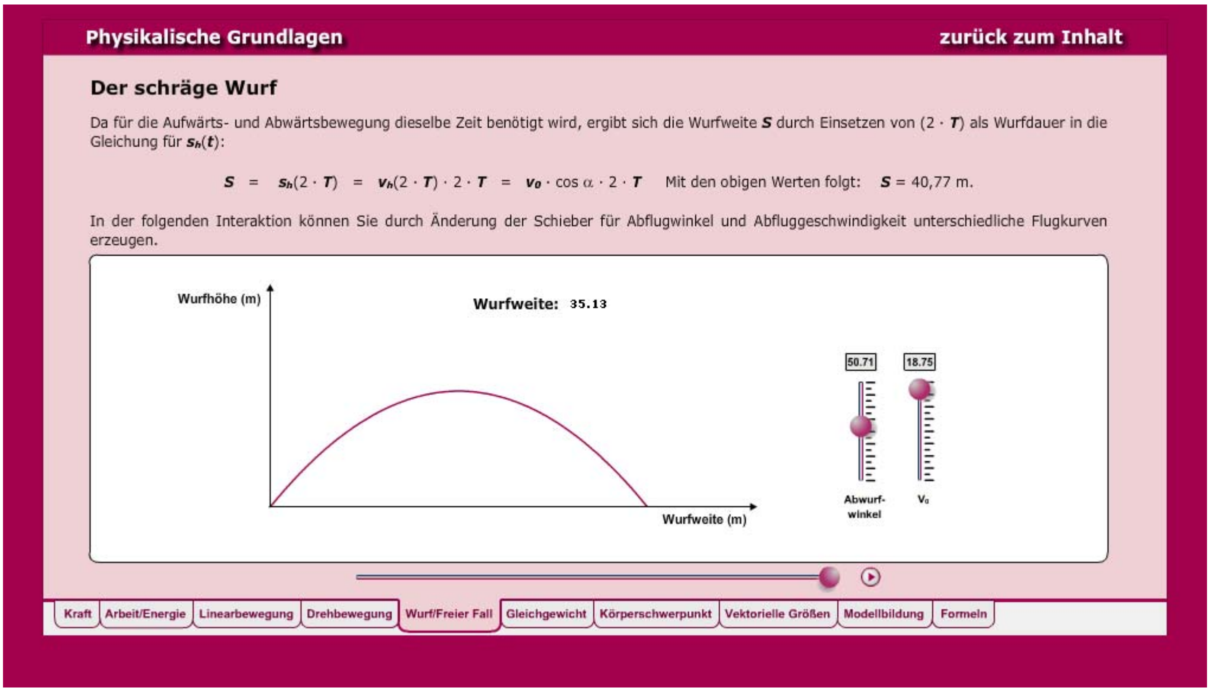
This paper introduces a teaching approach that aims to supplement classroom teaching as well as to compensate for the differences in learning prerequisites through an eLearning module. In addition, the approach aims to emphasize how a multimodal learning in the field of sports biomechanics may be established by a multimedia learning environment. For that purpose, classroom teaching is combined with self-directed eLearning while structured in online learning sessions utilizing multimedia tools. For the latter, eLearning units were developed which high-light selected issues in sports biomechanics in combination with a discovery learning when solving applied problems outside of class. The theoretical foundation for this approach is based on the levels-of-processing theory by Craik & Lockhardt (1972) and on the encoding specificity principle by Tulving & Thomson (1973).

The eLearning module for the biomechanical analysis of motor performance in sports (eLeM-BAMPS) was developed between 2007 and 2009 at the Institute for Sports and Sport Science and the Department for Teaching Physics (Prof. Wodzinski) at the University of Kassel in Germany. The project was financially supported by the State Ministry for Science and Arts in Hessen (HeLPS – Hessian eLearning-Projects in Sport Science). A web-geo design was used as a framework consisting of Macromedia flash films as constituting elements. All flash films are organised within a menu structure such that the eLeM-BAMPS may be used as a contribution to class room teaching as well as a possibility for self-directed learning on selected issues.

The eLeM-BAMPS is structured in two levels (Biomechanical Issues in Sports and Foundations in Mechancis). While the sports relevated issues refer to the basic motor skills of walking, jumping, throwing, and rotating the relevant principles and laws in physics are subdivided in widely documented electronic index-cards allocated on the bottom section of the computer screen.

Structure

While navigating through the sports related issues students may at any time open the index cards providing extensive information about the underlying principles in physics (see Fig. 1 on understanding of flight trajectories and the laws of throwing in physics). Various practical experiments are offered to perform simple data acquisition or to gain practical experience promoting students' interest and commitment to the issues discussed. For example, when working on the biomechanical principles of rotational skills students may examine the effects



of different moments of inertia to perform a somersault into proper stance (see Fig. 2).

Figure 1. Screen shot image showing a brief introduction to laws of throwing (in German language). In this particular flash film formulas are introduced for the throwing distance S based take-off angle α and the take-off velocity v0. Students may change both parameters to find about the effects on the flight trajectories and the throwing distances S.

A practical example with simple data acquisition: In soccer, long throw-ins from the side may be used as a strategic manoeuvre to approach the goal directly after a ball-out situation. Some players (e.g. Rory Dunlap from Stoke City in the English Premiership) have the ability to throw-in from the side as far as the middle of the penalty area. However, for such throw-ins, optimal take-off angles are found close to 30 degrees (see:

http://physicsworld.com/cws/article/news/24058 - January, 24th 2006) towards the horizontal plane counter to what would be expected from elementary physics. Students working on the sports relevant skill of throwing will be introduced to the basic issue by the above website document. Next, they will be asked to elaborate on the laws of throwing in elementary physics and to discuss the apparent disagreement with their physics and PE teachers. For the practical data acquisition, they will be asked to record video displays of throw-ins with their cell phone cameras and to analyse the resulting video files with some freeware on the internet. Such freeware is offered by various physics departments in the internet (e.g. http://didaktik.physik.uni-essen.de/viana/ or http://wswww.physik.uni-mainz.de/Lehramt/ ViMPS/ in Germany).

Students will learn to digitize video displays and to gain some numerical data on soccer throw-in angles. They will be asked to create a little presentation about their project and to look for possible causes related to the disagreement between observed optimal throw-in angles in soccer and take-off angles based on elementary physics.

All in all, the eLeM-BAMPS consists of 160 pages text and formulas, 83 illustrative video clips, 68 images, 76 graphical animations and interactive assets plus various experimental tasks regarding some simple data analysis.

Figure 2. Screen shot image showing an asset for the user to play with different moments of inertia when being asked to execute a computer animated somersault movement into proper stance (in German language). While the dummy will run up from the right side and take-off the user will have to change the moment of inertia during the flight to have the dummy land in upright stance. right side: scroll button to select different moments of inertia (from large to small), bottom row: index cards to open up flash films regarding the relevant principles and laws in physics (e.g. force, work/energy, linear and angular motion, throws and free falls, equilibriums, vector entities in physics, simple biomechanical models, formulas).

Evaluation

The benefits as well as the usability of the eLeM-BAMPS were assessed in a seminar on

"Biomechanical Principles in Sports" at the University of Kassel during the winter term of 2009. Eighteen students were evaluated. While all students participated on the weekly meetings including teaching with powerpoint presentations and discussion parts that were arranged by a biomechanics teacher 9 randomly assigned students (EG = experimental group) were asked to additionally work through selected sessions of the eLeM-BAMPS online at home. These sessions referred to the learning topics discussed earlier in class. No mandatory online learning times were required. Therefore, the evaluation aimed to assess the benefits of the eLeM-BAMPS as an additional learning occasion aside from classroom teaching. At an earlier stage of their academic program, all students had attended a lecture on an introduction to Exercise Science and Movement Science in Sports (including the basic principles of a biomechanical analysis of performance in sports). They had studied as much as 7 semesters majoring in sports science (and an additional second subject) aiming for a state degree to become a PE teacher.

All participants were asked to rate the quality of the seminar presentations. A questionnaire regarding basic biomechanical knowledge was given at the beginning and the end of the semester. For a further evaluation of the eLeM-BAMPS all students were asked about their motivation and learning strategies (SELLMO-ST by Spinath et al., 2002). In addition, students working with the eLeM-BAMPS were asked to evaluate the quality and the usability of its contents (Meier, 2006; Mueller & Danisch, 2007; Wiemeyer, 2003) on a 5-point scale (5 = absolutely agree to 1 = absolutely disagree). Both subgroups were examined for their performance in the final exam.

Results

For the classroom meetings including presentations and discussions, a mean rating of 3,55 (± 0,56) was given by the 18 participants. Fifty-four percent of the ratings were positive (ratings 4 and 5) and only 1% of the seminar participants found the seminar rather inadequate (ratings 1 and 2). No significant differences were found in the final exam results between the EG and the remaining seminar participants. The same was true for the questionnaire regarding basic biomechanical knowledge prior to and after the seminar. However, for both groups significant improvements were found in the biomechanical knowledge at the end of the semester.

As no mandatory learning periods were required, a wide spread of online learning phases throughout the course period were detected in the EG ranging between a total of less than one hour up to 6 h (average: 2,5 ± 2 h). There was a positive correlation between the time spent for the online work with eLeM-BAMPS and the performance in the final exam that slightly missed significance ($r = 0,66$ with $p = 0,06$). For the quality of the eLeM-BAMPS content a mean value of 3,33 (±1,04) was found. While 23% percent of the EG were not completely satisfied with the quality of the content (ratings 1 or 2) a total of 50% of the subjects were in favour of the eLeM-BAMPS sessions (ratings 4 and 5). The major concerns about the online learning objects referred to the deficits in the interactive structure and the references given in the flash film sections. A slightly more negative result was exhibited for the usability of the eLeM-BAMPS. Here, a mean value of 2,98 (±1,04) was found. The number of positive and negative responses (approximately 35%) was about the same.

The motivation for learning and performance was assessed through the SELLMO-ST questionnaire (Spinath et al., 2002). This questionnaire is used to evaluate the preferences and goals in learning and performance settings. Thirty-one items are grouped into 4 dimensions: learning goals, goal approaches, goal avoidances, and work avoidances. SPSS V12.0 (Module:

Factor Analysis) was used for the statistical analysis of the questionnaires. At the beginning of the seminar, a 4-factor solution (critical eigenvalue: 1,5) for the items was detected with an explained variance of 76 Percent.

For the motivation for learning and performance in the SELLMO-ST questionnaire similar answers in the index variables for the four dimensions were found prior to and after the seminar for the participants that did not engage in the eLeM-BAMPS work. In contrast, participants from the EG showed higher answer scores after the seminar for the dimensions goal avoidances and work avoidances. However, for these index variables, a significant interaction was missed in the analysis of variance between the testing time and the group variable possibly due to the small sample size.

Discussion

The above results may be interpreted as a tendency for the EG students to hide a lack in knowledge and in their cognitive skills such that they might feel incompetent (goal and work avoidances). According to Spinath et al. (2002), this result is associated with long term decreased performance. Therefore, self-directed learning may not always be beneficial. We speculate that if learners are allowed to freely choose how long to learn they may develop a tendency to avoid difficult tasks since being associated with much personal effort. If this is true self-directed learners may be tempted to reduce their personal efforts when being confronted with difficult tasks. For this case, self-directed learning maybe less efficient even when operating in multimedia learning environments. The motivation of the EG students maybe seen as an attempt to reduce their efforts which in turn may be associated with a decreased commitment to work and decreased performance. However, based on the small sample sizes particular care should be taken when generalizing the given data to larger populations.

Conclusion and Perspective

The results of the eLeM-BAMPS evaluation can be summarized as follows:

- All in all, the formal aspects of the eLeM-BAMPS contents were positively rated by the online learners. However, to the learners' opinion the interactive structure and the references should be improved.
- It was surprising to find out that a self-directed eLearning with learners having the freedom to choose when to learn and how much to learn may not provide beneficial results. The responses to the SELLMO-ST questionnaire showed that eLearners may develop strategies to avoid difficult issues, reduce their amounts of work invested, and their willingness to document their learning performance when being left alone with the learning material.
- While both groups improved their knowledge on basic biomechanical issues no differences were found in the final exams between eLearners and students who merely attended the seminar meetings.

In summary, we may conclude that the eLeM-BAMPS material should be used in self-directed learning settings only with learners having a precise guideline on exactly what to do and how long to do it. eLearning sessions should be limited to less extensive parts. In addition, particular help has to be provided for difficult learning sections.

For the use of the eLeM-BAMPS as an addition to normal classroom teaching, distinct issues should be outlined to interlink presentations and discussions in the class with eLearning sessions at home. Students should be encouraged to prepare classroom meetings by collecting information in the internet, recording video displays, and analysing kinematic data with freeware programs. Such learning settings would focus on the interaction between classroom meetings and online learning rather than a self-directed learning only.

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Modeling Constraints in Putting: The ISOPAR Method

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Abstract

One of the main theories in ecological psychology is the theory of affordances. Affordances are opportunities for action which are provided by the environment in which the action takes place and are action specific. So affordances describe how the environment allows, supports and constrains an action. The idea of studying the affordances can also be applied to sport, in this case to putting in golf, to gain insight into how performance is influenced by the sport specific environment. During tournaments, discrete experiences of players while performing a putt were collected for several rounds at one green. Using the ISOPAR method (Stöckl et al., 2011) all the single experiences of one round of the different players were transformed into a continuous average experience of the field across the whole green. Based on ISOPAR maps we can visualize the affordances and constraints which influenced the field's play. According to the number and the arrangement of the *iso*-lines on the ISOPAR maps we can identify areas on the green where the play of the field was constrained heavily by gradients on the green's surface and/or distance to the cup.

KEYWORDS: ISOPAR METHOD, GOLF, MODELING, ECOLOGOCAL PSYCHOLOGY, CONSTRAINTS

Introduction

In ecological psychology one of the "conceptual pillar(s) of the ecological approach to perception and action" (Fajen, Riley & Turvey, 2009, p.79) is Gibson's theory of affordances (1966, 1977, 1986). Affordances, a term coined by Gibson, are opportunities for actions which are provided by the environment in which an individual plans to perform an action and those planned actions differ between individuals. This means an action of an individual is supported, as well as constrained by the constitution of the environment.

Affordances can be roughly separated in two categories, body-scalded affordances and action-scaled affordances, but of course not all affordances can be put in only one of two categories properly because they are a mixture of both. Body-scaled affordances are constrained by an individual's body dimensions and can be described by the relation between a measurable dimension of the individual's body and a complementary property of the environment (Fajen et al., 2009). An example of body-scaled affordances is Warren's (1984) research on stair climbing. He found that a stair is climbable for a person if the stair's height is less than or equal 0.88 times the person's leg length, although following the results of the stair climbing study of Konczak, Meeuwsen & Cress (1992) it becomes clear that if a stair is climbable is not only determined by body size of a person but also by other factors like the age of a person. Action-scaled affordances are constrained by an individual's action capabilities. The perception of these affordances is a decisive factor for a successful performance (Fajen et al., 2009). There are only a few studies which have looked action-scaled affordances. For instance, Oudejans, Michaels, Bakker & Dolné (1996) found that in their study about the perception of catchableness of flying balls judgments of catchableness match actual catchableness quite well.

Fajen et al. (2009) also pointed out the potential of the theory of affordances for studies of perception and action in sport. Thus we applied this idea to golf or more specifically putting to gain insight into how the affordances provided by the surface of the green influence the performance of golfers. Continuing Gibson's idea in this case the environment is the green and the individual is a human being: the golfer. On the green there are two detached objects, the ball which affords (among other affordances) to be moved by rolling on the green after being struck and the club which affords (among other affordances) someone to grasp it and strike the ball. The green itself affords the ball rolling on it because of its surface which is rigid, horizontal, nearly flat and grassy, mostly shortly cut, and has a small hollow somewhere, the hole. The ball fits in this hollow and hence the surface of the green fulfils the physical conditions for the idea of putting and thus affords a golfer to perform this action.

Of course the success of this action also depends on the interaction of several abilities of the golfer. Depending on the ball location relative to the cup, the player has to view the surface of the green and devise the appropriate tactic to hole with as few strokes as possible. In order to do this the player must grasp the club and manipulate it in such a way that the force applied to the ball from the club allows the devised tactic to be realized. According to Haken & Schiepek (2010), from a macroscopic point of view, all these interacting actions can be treated as one synergetic system which also emphasizes the tight coupling of perception and action. As mentioned above, this synergetic system is affected by an input in terms of information about affordances and constraints provided by the green and is relative to the ball's location on the green.

In this work we focus on the outcome of the action with respect to this synergetic system. We have studied the experiences of players trying to hole out and how the green affords and constrains this goal. Hence we focus the action-scaled affordances. The affordances which the green offers are that there are, theoretically, several trajectories from every ball location on the green to the hole which, because of physical laws, allow the ball to roll into the hole. However, there are some constraints which make it more difficult for the golfer to hole out. In this case constraints are the gradients of the green; more specifically the lateral slope (break), the uphill or downhill situations (elevation), and the distance between the ball location and the hole. Another constraint is the green speed which is determined mainly by the length of the grass and hence specifies the resistance which decelerates the rolling ball. But because the grass is of the same length across the whole green we can ignore the green speed as a constraint.

For this study we collected the experiences of discrete actions of different golfers on the ninth green at the Augsburg Golf Club in Burgwalden, Germany. The experiences are represented by the position of the ball on the green and the number of putts the golfer had to take from this position to hole out. The number of putts is used as an indicator for identifying areas as more difficult. Our assumption is that, in general, difficult positions require more shots to be taken to hole out.

Gibson (1977) also points out that support of affordances is specific to the individual, the golfer in our case, and cannot be treated as an abstract and measureable physical property. Therefore we cannot measure affordances and constraints as we can measure physical properties.

The aim of this study was to transform all the discrete experiences to continuous values across the whole green using the ISOPAR method (Stöckl, Lamb & Lames, 2011). According to this method, the continuous values represent a kind of average experience of the field. With these data it is possible to visualize the support of affordances and constraints relative to the average performance of the field by calculating ISOPAR values and finally ISOPAR maps.

Methods

This section provides an overview of the data collection and the application of the ISOPAR method (for a more detailed explanation see Stöckl et al. (2011)). Ball locations were recorded by a team of observers situated around the green that was analysed. Data reported in this paper span two tournaments played at the Golfclub Augsburg in Burgwalden, Germany: the 2009 Bavarian Junior Championship and the 2010 Augsburg Classic (EPD Tour). The Augsburg Classic is a tournament on the EPD Tour, which is a professional tour in Europe designed to prepare golfers for competition on the European PGA Tour.

Data Collection

Measuring the Green

The green of the ninth hole at the Augsburg Golf Club in Burgwalden was measured by professional surveyors. They collected 563 measuring points across the green, the edge of the green and the edge of the fringe. The measuring points are represented as triplets (x,y,z). x,y values represent the position on the green and the z value is the height where the lowest area of the green has the value 0 and all other heights are indicated respectively to the lowest one.

Recording Ball Locations

Ball locations were collected from two tournaments at the Golf Club Augsburg: the 2009 Bavarian Junior Championship (BGV), and the 2010 Augsburg Classic (EPD). There were two rounds played during the Bavarian Junior Championship from which ball locations on the ninth green were collected. At the 2010 Augsburg Classic, three rounds were played with a cut after the second. Ball location data were collected from the ninth green for all three rounds.

At the green two observers were positioned with a good view of the green's surface. Data were recorded as triplets (*x,y,z*), where *x* and *y* represent the position of the ball on the green and *z* represents the number of shots required to hole out from that position. The *x,y* coordinates were estimated by the observers on a map of the green, on which a grid (distance between grid nodes was 0.25 m) was drawn. Observers estimated each ball position on the green and assigned it to one of the grid nodes. To ensure the quality of these estimations, inter-observer reliability was assessed using a sub-sample of putts. The estimations of the two observers were highly correlated in both tournaments. (Junior: $n = 56$, $r_x = .998$, $r_y = .984$; Professional: $n = 45$, $r_x = .991$, $r_y = .979$). Admittedly, the high correlation coefficients could be considered partly artefact (heterogeneous measuring points) resulting from the way ball positions were estimated, but the achieved precision seems to be satisfactory for the purposes of this study.

The ISOPAR Method

Below is an explanation of the calculation of ISOPAR values and ISOPAR maps. The method is performed in four steps using common MATLAB procedures. Because these steps are explained in detail elsewhere (Stöckl et al., 2011) only a summary is provided.

1. A two dimensional grid (d=0.25 m) is assigned to the green. This results in a set of grid nodes represented by tuples (x_{ij}, y_{ij}), $i = 1, \dots, m$, $j = 1, \dots, n$, on which the following steps are based.
2. At each grid node (x_{ij}, y_{ij}), ISOPAR values z_{ij} are calculated using an exponential smoothing algorithm. To calculate the ISOPAR value for one grid node all ball locations are ordered in ascending order (the nearest ball location first) according to the Euclidean distance d_{ijp}, $p = 1, \dots, q$ (q = number of ball locations of the sample), to this grid node. In the resulting ascending order, (d_{ijr}, z_r) represents the ball location with shortest distance to the respective grid node and (d_{ij1}, z_1) represents the ball location with the largest distance to the respective grid node. The corresponding ISOPAR value is calculated by the exponential smoothing
$$z_{ij} = \alpha \sum_{k=0}^{r-2} (1-\alpha)^k z_{r-k} + (1-\alpha)^{r-1} z_1,$$
where $0 \leq \alpha \leq 1$ is the smoothing parameter (Hamilton, 1994).
3. Using a spline interpolation, continuous ISOPAR values are calculated for the whole green based on the ISOPAR values at the grid nodes from the step before. To get a smooth surface without rough edges a slightly smoothing, cubic spline interpolant $f(x, y)$ is calculated by
$$\min_f \beta \sum_{i=1}^{n} \sum_{j=1}^{m} (z_{ij} - f(v_{ij}))^2 + (1-\beta)\lambda \iint \left(D^2 f(x,y)\right)^2 dxdy,$$
where
$$D^2 = \frac{\partial^2}{\partial^2 x} + 2\frac{\partial^2}{\partial x \partial y} + \frac{\partial^2}{\partial^2 y},$$
v_{ij} denotes the vector with entries $\binom{x_{ij}}{y_{ij}}$, $\lambda = 1$ in our case and β is the smoothing parameter (Fahrmeir, Kneib, & Lang, 2009).
4. The ISOPAR values are used to calculate *iso*-lines and, finally, the ISOPAR map. *Iso*-lines are calculated in 0.2 ISOPAR value intervals. For example, the *iso*-line at interval 1.8 is calculated as the intersection line between the ISOPAR surface and the plane which is parallel with distance of 1.8 ISOPAR value to the x-y-plane by
$$\begin{pmatrix} x \\ y \\ f(v) \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 1.8 \end{pmatrix} + \mu \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} + \vartheta \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix},$$
where v denotes the vector with entries $\binom{x}{y}$ and $\mu, \vartheta \epsilon \mathbb{R}$.

Reliability and Validity of ISOPAR Values

Figure 1 visualizes the distribution of the ball locations (red dots) from the first round of the EPD 2010 tournament on the ninth green at the Augsburg Golf Club in Burgwalden. We can recognize that the ball locations are not distributed equally on the green. There are many ball locations around the pin (black dot) and as distance to the pin increases the frequency of ball being located in these areas decreases. Thus, there are areas on the green where nearly no balls are located and hence nearly no information about experiences of players' performance in those areas. Consequently, the calculation of ISOPAR values at grid nodes in these areas are based on ball locations and information which are further away.

The idea of the ISOPAR method is to calculate a continuous surface of ISOPAR values for the whole green. But there cannot be ball locations everywhere on the green for many reasons. On the one hand there are areas where the slope is too great for a ball to remain at rest. On the other hand the calculation of ISOPAR values is based on the ball locations of a certain sample which is not large enough so that there can be ball locations everywhere on the green. Such a sample consists of all ball locations on the green of all players of the field in the tournament of one round and represents the experience of this field in this round. Hence, the interpolated surface of ISOPAR values is round specific, pin location specific (which changes every round in tournaments) and field specific and represents an average experience for this field in this round with this pin location. However, the ISOPAR values do not visualize the difficulty of a green in general.

To confirm the reliability of the ISOPAR values the ISOPAR method should be tested for sensitivity with respect to outliers, which are ball locations in areas where the number of strokes to hole out is much higher or much lower than the number of strokes remaining for the other ball locations in this area.

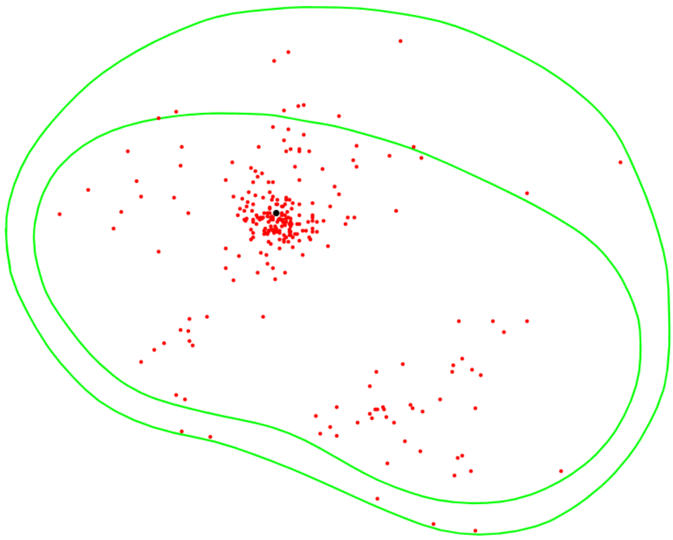

Figure 1: Two dimensional map of ninth green at the Augsburg Golf Club in Burgwalden including the ball locations of round 1 of EPD 2010 (red dots) and the pin location (black dot). The outer green line represents the edge of the fringe and the inner green line the edge of the green.

Results & Discussion

Figure 2. (a) (left) contour map of ninth green at the Augsburg Golf Club in Burgwalden, Germany, with the ISOPAR map of this green of round 1 of BGV 2009 superimposed. (b) (right) contour map of ninth green at the Augsburg Golf Club in Burgwalden, Germany, with the ISOPAR map of this green of round 1 of EPD 2010 superimposed.

One of the results of the ISOPAR method are ISOPAR maps (Stöckl et al., 2011). The maps show a two dimensional map of the green with *iso*-lines superimposed. According to Stöckl et al. (2011), the *iso*-lines represent lines of equal average number of shots until the ball is holed out and ISOPAR values represent an average performance of all players who played at this hole in one round. Accordingly, statements made about constraints are relative to the performance of the field.

In figure 2 there are combinations of a contour map of ninth green at the Augsburg Golf Club in Burgwalden and different ISOPAR maps, with *iso*-lines of interval 0.2 ISOPAR value, of the same green of different tournaments. In figure 2a) the ISOPAR map of the first round of the BGV 2009 tournament and in figure 2b) the ISOPAR map of the first round of the EPD 2010 tournament are superimposed on the contour map. Contour lines are represented in 0.1 m intervals of elevation with changing colors. Brighter colors represent higher values of elevation. The ninth green at Augsburg Golf Club is very undulated, these constraints are more easily visualized by including the contour maps. Consequently, this green provides additional constraints to putting other than distance. The influence of break and elevation change relative to the ball and pin positions on the green.

Generally we can notice that the field's play is constrained by the green because of the existence of several and differently arranged *iso*-lines in figure 2a) and 2b). This implies that the field was not able to hole out with only one putt with respect to the ball's position on the green and suggests that play is constrained. Because of the undulated green difficulty cannot be assigned to a certain area because of only one specific constraint. We can only assess difficulty to an area subject to the constraint which is caused by the interaction of the three constraints: break, elevation and distance. Figures 2a) and 2b) both show that the influence of distance (as a constraint) increased as distance to the pin increased, relative to the influence of other constraints. Furthermore, beyond the densely packed *iso*-lines near the hole, contours still exist yet are not as influential beyond the critical distance visualized in figure 2.

In figure 2a) an area around the pin can be identified where *iso*-lines are densely packed and roughly form ellipses. There the interaction of distance, elevation and break seemed to constrain the play of the juniors more than the professionals. Whereas in a very small area around the pin, the area within the first two *iso*-lines, downhill putts were easier to play than uphill putts shown by the proximity of the second *iso*-line at the downhill side of this area. As the putting distance increases beyond the area contained within the second iso-line, uphill putts were shown to be easier to play than downhill putts according to the density of the iso-lines associated with the respective putting directions. Nevertheless, uphill as well as downhill putts were still heavily constrained by distance, break and elevation as the density and number of *iso*-lines illustrate.

In figure 2b) a larger area around the pin can be identified where the *iso*-lines are more circular and centered around the pin. Therefore the interaction of break, elevation and distance constrained play of the field more equally with the exception of a few distortions of the circularity of the iso-lines. In this area the *iso*-lines are also close but not as close as the juniors, as shown in figure 2b). Therefore, the play of the professionals was influenced by the constraints although not as severely as the juniors were when putting in close proximity to the pin.

Conclusion

Overall, influence of the affordances and above all constraints provided by the green on the play of the field can be visualized using the ISOPAR method. The affordance provided by the green to the golfer is visualized by the number of *iso*-lines being finite. This means the field was able to hole out after an average number of putts – a number which can be determined. The constraints provided by the green are visualized by the form and arrangement of the *iso*-lines. Very close lines can be interpreted as areas in which the play of the field was highly constrained. Although the different constraints cannot themselves be visualized separately, the interaction of break, elevation and distance and their effect on the experience of the players can be visualized on ISOPAR maps, thus allowing new insight into behaviors and performance of golfers in competitive situations.

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