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Editorial

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Dear readers:

Welcome to the winter 2006 issue of the **International Journal of Computer Science in Sport** (**IJCSS**).

Two original papers, three reports as well as extended abstracts of selected papers presented at the Workshop on "Computer Science in Sport" in Magdeburg (June 22 - 24, 2006), organized by the section "Computer Science in Sport" of the German Society of Sport Science have been included within this issue.

Peter O'Donoghue investigates the accuracy of modeling techniques for predicting the outcome of sports performances. He evaluates the models by comparing the predictions with the actual results of the FIFA world cup 2006.

In the paper by **Nicholas Vernadakis, Andreas Avgerinos, Eleni Zetou, Maria Giannousi** and **Efthimis Kioumourtzoglou** different instruction methods were compared with regard to their effectiveness for cognitive learning and skill development in the long jump. A combination of multimedia computer assisted instruction with traditional instruction showed the best results.

Three project reports of work in progress (**Jürgen Perl**, **Daniel Memmert**, **Julian Bischof** and **Christian Gerharz**; **Jürgen Perl**; **Jürgen Perl** and **Stefan Endler**) present research activities in the area of modelling.

Eleven extended abstracts from lectures presented at the Workshop on Computer Science in Sport at the Otto-von-Guericke-University in Magdeburg in June, 2006, give a good survey on topics currently addressed in Computer Science in Sport.

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

Best wishes for 2007!

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The Effectiveness of Satisfying the Assumptions of Predictive Modelling Techniques: An Exercise in Predicting the FIFA World Cup 2006

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Abstract

The assumptions of statistical procedures are enforced more rigorously in some disciplines than in others. Outliers are often removed from data sets due to concerns over measurement error. However when predicting the outcomes of sports performances, such outliers represent real and valid performances such as Germany's 8-0 win over Saudi Arabia in the 2002 FIFA World Cup. Previous research into the accuracy of predictive modelling techniques has provided examples of where models based on data that violate the relevant assumptions is greater than that of models where the assumptions were satisfied. The purpose of this investigation was to intentionally develop two sets of 6 models; one set being based on untransformed data that violated the assumptions of the modelling techniques and a second set where the data were transformed and outliers were removed in order to satisfy the assumptions of the modelling techniques. Data from 477 pool matches and 165 knockout matches from World Cups, European Championships, Copa America tournaments and African Cup of Nations tournaments from May 1994 to February 2006 were used to produce predictive models of match outcomes (win, draw or lose) or goal difference with respect to the higher ranked teams within matches according to the FIFA World rankings. The independent variables used were difference between the teams FIFA World rankings, difference between distance from capital city to capital city of the host nation, and difference in recovery days from previous match within the tournament. The two sets of models were used to predict the 2006 FIFA World Cup and 22 human predictions and 20 weighted random predictions were also produced. An evaluation process marked the predictions with respect to the actual outcomes of matches in the 2006 FIFA World Cup out of a total possible score of 64 points. The mean accuracy of the models where the assumptions were satisfied was 38.67 points which was similar to the 39.00 points for those where the assumptions were violated. However, the best individual model was a simulator where the assumptions of the underlying multiple linear regression technique used were satisfied (44.00 points). The multiple linear regression based models were more accurate than those based on discriminant function analysis and binary logistic regression. The accuracy score of the 12 model based predictions of 38.83 ± 3.26 was significantly lower than the 42.95 ± 3.36 for the human predictions ($P < 0.017$) but significantly greater than the 31.05 ± 3.86 for the weighted random predictions ($P < 0.017$). These results provide evidence that challenges the value of satisfying the assumptions of discriminant function analysis, binary logistic regression and multiple linear regression.

KEY WORDS: PREDICTIVE MODELLING, STATISTICAL ASSUMPTIONS

Introduction

Forecasting is important in many fields including commerce, medicine and geology. The quality of models used to make forecasts depends on several factors including measurement issues and the validity with which the modelling technique can be applied to the data used to form the model. Measurement issues such as objectivity, reliability and validity are critically important to avoid the modelling techniques being applied to inaccurately measured values. Even when the measured values are reliable, there are assumptions of statistical techniques that statisticians recommend should be satisfied (Manly, 1994; Tabachnick and Fidell, 1996; Ntoumanis, 2001). Where such assumptions are violated, the resulting models are considered to be of limited validity.

Soccer has been used as an example of a forecasting problem to allow comparison of the accuracy of predictions based on human and artificial intelligence (Buchner *et al*., 1997). Soccer is a team sport with problems relating to time, space, information and organisation (Grehaigne *et al*., 1997) that influence the outcome of the matches in a way that makes the prediction of soccer matches particularly challenging. The complex nature of soccer and indeed other team and individual sports has lead to modelling techniques based on dynamic systems theory (McGarry *et al*., 2002;) to be applied to sports behaviour. Attempting to predict the outcome of the knockout stages of international sports tournaments is even more difficult as errors made at the pool stages will be propagated into the predictions of knockout matches. In previous prediction studies on the 2003 Rugby World Cup (O'Donoghue and Williams, 2004) and the Euro 2004 (O'Donoghue, 2005) soccer tournament that predictions based on models where the relevant assumptions were satisfied were not as accurate as predictions where the models violated those assumptions. Therefore, the purpose of the current investigation was to predict the pool and knockout stages of the 2006 FIFA World Cup before the competition commenced using pairs of models based on multiple linear regression, discriminant function analysis and binary logistic regression. Each pair of models included one where the data used to create the model were not transformed in any way and one where the data were transformed so that the assumptions of the modelling technique were satisfied. The pairs of models use the following techniques where the superior team within a match refers to the team ranked highest by FIFA and the inferior team referring to their opponents:

(a) Discriminant function analysis to predict the outcomes of pool matches (win, draw or loss for the superior team) and binary logistic regression to predict the outcome of knockout matches (superior team progressing or being eliminated).
(b) Multiple linear regression to predict the goal difference between the superior and inferior teams within matches. During the pool stages, values of between -0.5 and +0.5 were interpreted as draws. During the knockout stages, values of 0.0 and above indicated that the superior team progresses.
(c) Multiple linear regression with -0.5 and +0.5 (and 0.0 during the knockout stages) being replaced by cut-off values intended to produce a proportionate number of wins, draws and losses for the superior team (and proportionate number of matches where the superior team progresses during the knockout stages).

(d) Multiple linear regression correcting for regional biases in the FIFA World rankings. During the knockout stages, values between -0.5 and +0.5 were interpreted as draws. During the knockout stages, values of 0.0 and above indicated that the superior team progresses.
(e) Multiple linear regression correcting for regional biases in the FIFA World rankings. The cut off values of -0.5 and +0.5 (and 0.0 during the knockout stages) were replaced by cut-off values intended to produce a proportionate number of wins, draws and losses for the superior team (and proportionate number of matches where the superior team progresses during the knockout stages).
(f) A simulation based on multiple linear regression to determine expected results, correcting for regional biases in the FIFA World rankings and representing variability in performance with some teams being more consistent than others. The simulator was designed to produce a proportion of wins, draws and losses for the superior teams within matches that reflects the proportions observed historically.

A secondary aim of the study was to compare the accuracy of these quantitative predictions with a set of random predictions and predictions made by humans using qualitative methods.

Methods

Data Sources

All of the models used the same data set of international tournament soccer matches. The data set consisted of 7 variables for 612 World Cup, Copa America, African Cup of Nations and European Championship matches from 1994 to 2006. Matches prior to 1994 were not included because the 1994 World Cup was the first international tournament where teams had FIFA World rankings. There were 447 pool matches and 165 knockout matches within the data set. Each match was contested between two sides; the superior side (the higher ranked side according to FIFA) and the inferior side (the lower ranked side according to FIFA). As well as being identified, the sides were classified into region (Africa, Asia and Oceania, Western Europe, Eastern Europe, North and Central America or South America). The outcome variable was the difference in goals between the two sides (superior team's goals – inferior team's goals) after 90 minutes plus any injury time. A categorical version of this variable was also included classifying matches as wins, draws or losses for the superior team. All knockout stage matches were classified as wins or losses depending on the actual outcome including any extra time and penalty shoot outs. In addition to the regions of the two sides and the two versions of the match outcome, there were 3 independent variables which were differences between the superior and inferior sides contesting the match. These were:

- Rankδ: Difference between the FIFA world rankings of the superior and inferior teams involved in a match. It was decided to use FIFA World ranking rather than FIFA World ranking points due to changes in the scale of measurement for FIFA World ranking points that have occurred between 1994 and 2006.
- Distδ: Difference in distance traveled to the tournament by the superior and inferior sides. For each team involved in a match, the distance traveled was estimated by the giant circle distance between the capital city of the country and the capital city of

the host nation. This was obtained from an internet based distance calculator (Indonesia, 2006).

- Recδ: The difference in the recovery days from the previous matches within the tournament played by the two teams (+1 meant the superior team had an extra recovery day, -1 meant that the inferior team had an extra recovery day and 0 meant the two teams had the same number of recovery days from their previous matches).

Some of the modelling techniques being used had assumptions that could be satisfied if normally distributed independent variables were used. Kolmogorov Smirnov tests revealed that none of these three independent variables were normally distributed ($P < 0.05$). The logarithmic, square root and arcsine transformation procedures recommended by Nevill (2000) failed to produce normally distributed variables. It was therefore decided that mapping functions would be used to map the variables onto a standard normal distribution with a mean of 0 and a standard deviation of 1. For each of the three independent variables in the data set in turn, the 612 values were arranged in ascending order and mapped onto the values of the standard normal curve. Where the variable contained multiple cases of the same value (for example there were 23 matches where there was a difference of 10 between the two teams' FIFA World rankings) the mean of the 23 corresponding values from the standard normal distribution was taken as being mapped onto by the original value. These mapping functions allowed three new independent variables ZRankδ, ZDistδ and ZRecδ to be included in the data set. Kolmogorov Smirnov tests revealed that ZRankδ and ZDistδ were normally distributed ($P > 0.2$) but that ZRecδ was not ($P < 0.05$).

Prediction Techniques

Discriminant Function Analysis and Binary Logistic Regression (Violates Assumptions)

Discriminant function analysis was performed on the 447 cases of pool matches from previous international soccer tournaments to predict group membership according to match outcome (wins, draws and losses for the superior team) using Rankδ, Distδ and Recδ as predictor variables. This was done in SPSS Version 12.0 (SPSS Inc., Chicago Il) with a territorial map and the two canonical discriminant functions being recorded. SPSS Version 12.0 (SPSS Inc, Chicago, Il) was also used to perform the binary logistic regression on the 165 knockout matches from previous international tournaments.

Discriminant Function Analysis and Binary Logistic Regression (Satisfies Assumptions)

Neither Recδ nor ZRecδ were normally distributed and so neither was included in the discriminant function analysis based model that satisfied its assumptions. An iterative process of testing the assumptions of the method and removing outliers removed 10 pool match cases from the data set before the assumptions were fully satisfied. Binary logistic regression does not have any assumptions relating to the distribution of predictor variables and so the untransformed Rankδ, Distδ and Recδ variables were used in the binary logistic regression. Furthermore, no outliers were found when the residual values of the binary logistic regression ere examined and all other assumptions of the method were satisfied without any need to transform the variables. This meant that the only difference was that the knockout matches to be forecast were different as a result of different discriminant function analyses being done within the predictions of the pool matches.

Multiple linear regression (violates assumptions)

SPSS Version 12.0 was used to perform the multiple linear regression to predict goal difference between the superior and inferior teams within the pool matches and knockout matches respectively. When the regression equation was applied to the new cases from the pool matches of the 2006 FIFA World Cup, goal difference values between -0.5 and +0.5 were interpreted as draws. When using the regression equation to forecast the outcomes of knockout matches, goal difference values of 0.0 and above were interpreted as wins for the superior side within matches.

Multiple linear regression (satisfies assumptions)

Although multiple linear regression does not impose restriction on the distribution of independent variables entered into the model, it was decided to base this model on ZRankδ, ZDistδ and ZRecδ rather than Rankδ, Distδ and Recδ to help eliminate outliers and achieve normality in the residual values produced. The iterative process of testing the assumptions and removing outliers reduced the data set to 433 pool matches and 158 knockout matches.

Multiple linear regression with proportionate outcomes (violates assumptions)

When inspecting the actual and predicted goal differences within matches, it was clear that there was much greater variability in the actual goal differences (±1.69 in pool matches and ±1.62 in knockout matches) than the predicted goal differences (±0.45 in pool matches and ±0.37 in knockout matches). Indeed, losses by the superior team in pool matches were only being predicted when the superior team had to travel considerably further to the tournament than the inferior team. Wins, draws and losses were predicted more proportionately by replacing the cut-off values of -0.5 and +0.5 for draws in pool matches by 0.2702 and 0.4985 respectively. The cut-off value of 0.0 and above for wins in knockout matches was replaced by 0.3082 and above to predict wins for the superior team more proportionately.

Multiple linear regression with proportionate outcomes (satisfies assumptions)

Predicted goal difference values of between 0.2291 and 0.5839 were forecasted as draws for the pool matches and predicted goal difference values of 0.2552 and above were predicted as wins for the superior team within the knockout stages.

Multiple linear regression addressing regional biases (violates assumptions)

Examination of the residuals for the 176 World Cup matches within the data set revealed that the FIFA World rankings were higher than one might expect for countries from some confederations and lower than expected for other confederations. The mean residual for each region is shown in Table 1. These regional differences were a source of variability in the model and so a regionally adjusted predicted goal difference for each match was determined by subtracting the mean regional residual for the superior team and adding the mean regional residual for the inferior team. The regression equations were then determined so that regional modifiers could be applied. This model used the original cut-off values of -0.5 to +0.5 to represent draws in pool matches and 0.0 and above to represent wins for the superior team in knockout stage matches.

Table 1. Regional residuals in predicted goal differences within the model that violates the assumptions of multiple linear regression.

Region	Mean Residual
Africa	-0.26
Asia	-0.86
Western Europe	+0.21
Eastern Europe	-0.49
North and Central America	-0.50
South America	-0.04

Multiple linear regression addressing regional biases (satisfies assumptions)

The residuals for the 170 World Cup matches that remained in the data set, once outliers had been removed, were examined leading to the mean residuals shown in Table 2 being computed. This model used the original cut-off values of -0.5 to +0.5 to represent draws in pool matches and 0.0 and above to represent wins for the superior team in knockout stage matches.

Table 2. Regional residuals in predicted goal differences within the model that satisfied the assumptions of multiple linear regression.

Region	Mean Residual
Africa	-0.12
Asia	-0.73
Western Europe	+0.05
Eastern Europe	-0.29
North and Central America	-0.13
South America	0.00

Multiple linear regression addressing regional biases interpreted proportionately (violates assumptions)

This model used the regional modifiers in Table 1 but predicted goal difference between 0.2194 and 0.5500 were interpreted as draws in pool matches and predicted goal difference values of 0.2519 or greater were interpreted as wins for the superior team in knockout stage matches. These cut-off values were chosen to intentionally predict a proportionate number of wins, draws and losses for the superior teams within matches.

Multiple linear regression addressing regional biases interpreted proportionately (satisfies assumptions)

This model used the regional modifiers in Table 2 but predicted goal difference values between 0.2454 and 0.5943 were interpreted as draws for the pool matches and predicted goal difference values of 0.2280 or greater were interpreted as wins for the superior team in the knockout stage matches.

Multiple linear regression based simulation (violates assumptions)

In prediction studies done on the 2002 FIFA World Cup (O'Donoghue et al., 2004), the 2003 Rugby World Cup (O'Donoghue and Williams, 2004) and Euro 2004 (O'Donoghue, 2005) simulation models produced more accurate predictions than any other quantitative methods. Simulation has also been found to be more accurate than qualitative human prediction for the 1998 FIFA World Cup (Dyte and Clarke, 2001). The simulators used in the current investigation used values for each team's variability that were evidenced from previous international soccer competition. A further enhancement on the simulator used for the 2002 FIFA World Cup (O'Donoghue et al., 2004) was that regional biases in the FIFA World rankings would be addressed. During the process of producing the regional biases shown in Table 1, the mean and standard deviation for each team's residual within the complete data set of 612 matches was determined. The standard deviations were used as an indicator of each teams consistency with the most consistent of teams involved in the 2006 FIFA World Cup being Tunisia (SD for residuals = 0.95) and Italy (SD for residuals = 0.98) and the most inconsistent being Poland (SD for residuals = 3.05) and Portugal (SD for residuals = 2.73). The simulation system was implemented in MatLab version 7.0.1 (Mathworks Inc., Natick, Massachusetts). The system stored the FIFA World rankings, distances between capital city and Berlin, modifier due to region (determined from residual analysis) and SD in performance (determined from residual analysis). The system simulated the 2006 FIFA World cup 20000 times accumulating result and progression statistics. A process of backtracking from the final was used to determine the modal prediction made by the simulator.

Multiple linear regression based simulation (satisfies assumptions)

A second simulator was produced using the underlying regression equations derived from data that had satisfied the assumptions of the technique. The system stores the same variables as the previous simulator but also includes the necessary mapping functions to allow ZRankδ, ZDistδ and ZRecδ to be determined. The regional modifiers from Table 2 were used in this simulator. The system iterated the tournament 20000 times accumulating result and progression statistics, so that a single modal prediction could be determined.

Human predictions

A prediction form for the 2006 FIFA World Cup was distributed to academic staff and postgraduate students from a sport science department of a university. The form allowed the respondents to predict a win, draw or loss for the superior team in each of the 48 pool matches as well as predicting the teams reaching different points in the knockout stages. There were 22 human predictions provided before the World Cup commenced and these were included in the study. Each of these predictions was checked by the author to ensure that the pool results were consistent with the 16 teams predicted to participate in the 8 round 2 matches. Two of the human predictors were asked to clarify inconsistencies in their predictions and corrections were obtained from them before the World Cup commenced.

Weighted random assignment of results

The 447 pool matches and 165 knockout matches from previous international tournaments were divided into four and two partitions respectively based on gap in FIFA World ranking between the two teams in the matches. The number of wins, draws and losses for the superior teams in each partition allowed the proportion of matches resulting in each outcome type to be determined as shown in Table 3. These proportions allowed cut off probabilities to be determined so that random numbers between 0 and 1 could be used to predict wins, draws and losses. This process allowed the randomised results to be weighted so that a proportionate number of wins, draws and losses would be predicted for matches between teams separated by different numbers of places in the FIFA World rankings.

Table 3. Outcomes of previous matches and cut off probabilities used to produce weighted random results.

Difference in FIFA World rankings between superior and inferior teams within matches	Wins	Draws	Losses	Cut off for Loss (below)	Cut off for Win (above)
Pool matches					
1 to 7 places	41	34	35	0.318	0.628
8 to 19 places	54	26	35	0.304	0.530
20 to34 places	60	25	23	0.213	0.444
35 to 117 places	72	25	15	0.134	0.357
Knockout matches					
Same ranking	N/A	N/A	N/A	0.500	N/A
1 to 16 places	51	N/A	33	0.393	N/A
17 to 83 places	53	N/A	28	0.346	N/A

Evaluation Procedure

The predictions for each pool match were given 1 mark where the outcome is correctly predicted. Where the prediction was a draw but the actual match was won by one of the teams, 0.5 marks were awarded. Similarly, 0.5 marks were awarded where a win was predicted for one of the teams but the actual match resulted in a draw. The second part of the evaluation related to the predictions of knockout matches. The prediction models were awarded 1 mark for each of the quarter finalists successfully predicted, 1 mark for each semi-finalist and finalist successfully predicted, 1 mark if the winner of the third place play off was correctly predicted and 1 mark if the tournament winner was successfully predicted. This gave a maximum of 64 marks for each prediction.

The number of points awarded to each prediction at the various stages of the tournament was compared between quantitative, human and random predictions using a Kruskal Wallis H test. A P value of less than 0.05 was taken as being significant. Where a significant difference was found, Bonferroni adjusted Mann Whitney U tests were used to compare pairs of prediction types with a P value of less than 0.017 indicating a significant difference.

Results

Despite the 12 quantitative predictions being made using the same data, there were no two pairs of predictions that were the same for the 48 pool matches. Furthermore, no two quantitative models predicted the same first four teams in the same order. Table 4 shows that the accuracy of those models created with data that satisfied the assumptions of the methods involved is similar to that of models created with data that violated the assumptions. However, the most successful quantitative technique was the simulator where the data used satisfied the assumptions of the multiple linear regression technique used to model the expected results. The multiple linear regression based methods all performed better than those based on discriminant function analysis and binary logistic regression. As sophistication was added to the multiple linear regression based methods through proportionate outcomes, regional adjustment and representing team consistency, there was a general improvement in accuracy.

Table 4. Accuracy scores for the quantitative predictions.

Method	Data used violate assumptions	Data used satisfy assumptions	Mean
Discriminant Function Analysis / Binary Logistic Regression	35.50	32.50	34.00
Multiple Linear Regression (MLR)	35.50	37.50	36.50
MLR with proportionate outcomes	40.50	37.50	38.75
MLR with regional adjustment	41.00	41.50	41.25
MLR with regional adjustment and proportionate outcomes	40.50	39.50	40.00
MLR based simulation	41.00	44.00	42.50
Mean	39.00	38.67	38.83

Table 5 shows that the accuracy of the quantitative methods was between that of the weighted random predictions and the human predictions. This was the case overall and for the pool matches, quarter-finalists and semi-finalists. However, the only prediction to correctly forecast Italy to win the tournament was one of the 20 random predictions. The accuracy of the human predictions ranged from 33.0 to 47.5 while that of the random predictions ranged from 22.5 to 35.0. This meant that one of the quantitative predictions (discriminant function analysis and binary logistic regression where the data used to create the model satisfied the assumptions) and one of the human predictions performed worse than some of the random predictions. The simulator created with data that satisfied the assumptions of the underlying multiple linear regression technique used was the only quantitative method to perform better than the mean human prediction, with 8 of the 22 human predictions being more accurate.

Table 5. Mean accuracy score of different types of predictions at different stages of the tournament.

Stage / Total points allocated	Quantitative (n=12)	Human (n=22)	Random (n=20)	H_2	P
Pool matches /48	33.50±2.13	35.77±2.35 ^	27.10±2.94 ^&	37.5	<0.001
Quarter-finalists /8	4.17±1.03	5.55±1.06 ^	2.75±1.12 ^&	32.2	<0.001
Semi-finalists /4	1.00±0.74	1.41±0.91	0.85±0.67	4.8	0.089
Finalists / 2	0.17±0.39	0.18±0.40	0.20±0.41	0.1	0.972
Third place /1	0.00±0.00	0.05±0.21	0.10±0.31	1.5	0.479
Winners /1	0.00±0.00	0.00±0.00	0.05±0.22	1.7	0.427
Knockout stages /16	5.33±1.72	7.18±1.74	3.95±1.90 ^&	21.9	<0.001
Total /64	38.83±3.26	42.95±3.36 ^	31.05±3.86 ^&	37.2	<0.001

^ Mann Whitney U test revealed significantly different to quantitative predictions (P < 0.017).
& Mann Whitney U test revealed significantly different to human predictions (P < 0.017).

Discussion

In the current investigation the human predictions were significantly more accurate than those from the quantitative models that were developed. This is in contrast to previous research where quantitative methods were more accurate than human predictions for the 2002 FIFA World Cup (O'Donoghue *et al*., 2004) and the Rugby World Cup (O'Donoghue and Williams, 2005). The quantitative models did not consider all of the complex factors that the human predictors were able to such as non selection of some senior players, discipline of individual players, players missing due to injury, form in pre-tournament friendly matches and recovery from the domestic league competition that squad members would have been involved in.

The comparison of different types of modelling techniques reveals some similarities and differences to previous research. Overall the use of simulation provided the greatest success which agrees with previous prediction studies (O'Donoghue *et al*., 2004; O'Donoghue and Williams, 2005; O'Donoghue, 2005). The success of the simulation models has been attributed to the way the combination of conditional probabilities is dealt with during the process of inspecting progression statistics (O'Donoghue and Williams, 2004). The current study has applied three methodological advances to the multiple linear regression based methods used in previous prediction research. The first methodological advance relates to the interpretation of predicted goal difference. The use of -0.5 to +0.5 in previous research studies forecasted more draws than would have occurred in reality and very few upsets were predicted. Based on predicted values for previous cases, alternative cut off points between losses and draws as well as between draws and wins were determined so that a proportionate number of wins, draws and losses for the superior teams within matches would be predicted. There were 11 upsets in the 2006 World Cup. The four linear regression based models that used predicted goal differences between -0.5 and +0.5 to predict draws only successfully predicted 0.75 of an upset on average compared to the 2.18 average number of upsets successfully predicted by the 6 models where alternative cut off points were used. The second methodological advance was the use of residual analysis to identify regional bias in the FIFA World rankings. The evidence from previous World Cup tournaments was that teams from Eastern Europe, Central / North America and Asia do not perform as well as in World Cup tournaments as their FIFA World rankings would suggest. Two of the models without regional adjustment predicted the Czech Republic to win the World Cup, 1 predicted that USA would reach the semi-finals and 1 predicted that Mexico would reach the semi-finals. These inaccuracies were not present in any of the predictions where regional bias in the FIFA World rankings was addressed. The failure of any Asian teams to qualify for round 2 of the 2006 World Cup was successfully predicted by all 6 of the models that addressed regional bias. However, 4 of the other predictions forecasted Japan to reach round 2, 4 forecasted that Iran would reach round 2 and 2 predicted that South Korea would be in round 2. The third methodological advance is the use of residual analysis to identify variability in team performance within the simulation models. In 2002, Henry Stott of Warwick University (cited in O'Donoghue, 2005), recognised that the high degree of variability in the performances of France and Senegal made the pool match between them one of the 5 most likely upsets in the pool stages. While random variation in performance existed in the simulation models used in previous research in a way that generated a proportionate number of draws and upsets (O'Donoghue *et al*., 2004; O'Donoghue and Williams, 2005; O'Donoghue, 2005), all teams had the same variability imposed on them. The benefit of the approach used in the current investigation is that like Stott's Monte Carlo simulation of the 2002 FIFA World Cup, the consistency or inconsistency of different teams is represented.

The final area of discussion relates to the primary purpose of the current investigation which was to compare those models created using data that satisfied the assumptions of the models with those created with data that violated the assumptions. The methods section of the current paper has described the considerable effort required to satisfy the assumptions of some of these models. For example, when removing outliers from the data, the previous pool matches had to be inspected on 6 occasions and the previous knockout matches had to be inspected on 4 occasions as the decreasing variability caused by outlier removal introduced new outliers. Altogether 44 pool matches and 7 knockout matches from previous international soccer tournaments were removed from the data used so that the assumptions of the models were satisfied. These are not cases where measurement error has distorted the data (Vincent, 1999, p14-15), but real soccer matches where the results are historical fact. It is difficult to justify the effort in transforming data to satisfy the assumptions when the results of the current investigation reveal no benefit to this effort.

Conclusions

The current investigation has revealed no benefit arising from the effort of ensuring that data satisfy the assumptions of the modelling techniques used. More evidence is needed to support these assumptions if they are to be addressed by researchers into performance prediction in sport. The research has also revealed a regional bias in the FIFA World rankings and it is recommended that the ranking system is revised so that teams from all confederations are evaluated in a manner that is consistent with performance in inter-confederation competition such as the FIFA World Cup. Despite the methodological advances made in the models to build on previous predictive models, the accuracy of the forecasts was significantly lower than that of human predictions. Further work is required to introduce further variables, particularly process indicators related to known typical styles of play of different teams.

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Comparsion of Multimedia Computer Assisted Instruction, Traditional Instruction and Combined Instruction on Learning the Skills of Long Jump

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Abstract

The purpose of this study was to determine the effect of multimedia computer - assisted instruction (MCAI), traditional instruction (TI), and combined instruction (CI) methods on learning the long jump event. Forty-eight middle school students of seventh and eighth grade were randomly assigned into three teaching method groups: MCAI, TI and CI. Each group received ten 45-min periods of instruction divided into 4 sections: a) 5 min warm-up, b) 15-min instructional time c) 15-min main practice time and d) 10-min cool dawn and review. Students took pre-, post-, and retention skill test and written test covering rules and concepts of the event. Two-way analysis of variances (ANOVA), with repeated measures on the last factor, were conducted to determine effect of method groups (MCAI, TI, CI) and measures (pre-test, post-test, 1-week retention test) on knowledge and skill test. Post-test results indicated no significant differences between the groups concerning the written test. Nevertheless, the mean skill test scores of the TI and CI groups were significantly greater than MCAI group. Retention test results showed that groups retained the knowledge and skill learning. However, the mean skill test score of the MCAI group was significantly lower than the TI and CI groups. Conclusively, the CI method tended to be the most effective for cognitive learning and skill development.

KEY WORDS: INSTRUCTIONAL TECHNOLOGY; MULTIMEDIA SOFTWARE; TRADITIONAL INSTRUCTION; COGNITIVE LEARNING; MOTOR LEARNING; LONG JUMP.

Introduction

During the past three decades, a large number of meta-analyses have systematically examined the effects of technology on student outcomes. Overall, these meta-analyses have documented the positive effects of educational technology on student achievement (Schacter, 2001; Sivin-Kachala, 1998; Wenglinsky, 1998). These studies, reviews, and meta-analyses, however, typically look at different aspects or types of technology. Furthermore, this knowledge base has not really provided information on how to appropriately integrate and use technology in schools and classrooms. In addition, recent improvements regarding the quality and quantity of technology in schools suggest that technology in schools today is dramatically different from the technology that used in schools several years ago. This rapid growth and improvement in technology exceeds current knowledge of how to effectively use technology in schools (Allen, 2001) and suggests that the impact of technology is different today than it was in the past.

Several recent meta-analyses have focused on specific aspects of technology. Blok, Oostdam, Otter, and Overmaat (2002), for example, examined the effectiveness of computer-assisted instruction (CAI) programs in supporting beginning readers. Their review included 42 studies from 1990 onward, and they found the corrected overall effect size estimate was .19. Their findings were similar to earlier meta-analyses by Kulik and Kulik (1991) and Bangert-Drowns (1993), which also examined the effects of CAI and found it to have positive but small effects. Wiemeyer, (2003) reviewed nine meta-analyses of earlier and different multimedia issues and suggested that multimedia learning can be more effective and efficient than traditional learning. But this effect depends on many factors like the features of the learners, the teachers, the learning stuff, the type of learning, the features of the study, etc. Further, a meta-analysis of 167 studies (Bernard, Abrami, Lou, Borokhovski, Wade, Wozney, Wallet, Fiset and Binru Huang, 2004) concluded that a very weak learning advantage for multimedia in empirical studies is based on uncontrolled instructional methods.

Richardson, (1997) compared student perceptions and learning outcomes of computer-assisted instruction against those of traditional didactic lectures. He found that computer laboratory instruction enhanced learning outcomes in medical physiology despite student perceptions to the contrary. Other recent meta-analyses in technology have examined topics such as the effectiveness of interactive distance education (Cavanaugh, 2001), computer-assisted instruction in science education (Bayraktar, 2002), and computer-based instructional simulation (Lee, 1999). Furthermore, other recent meta-analyses have examined the effects of computer-assisted instruction on student achievement in differing science and demographic areas (Christmann & Badgett, 1999), microcomputer-based computer-assisted instruction within differing subject areas (Christmann, Badgett, & Lucking, 1997), and the effectiveness of computer-assisted instruction on the academic achievement of secondary students (Christmann, Lucking, & Badgett, 1997).

One area in which there have not been many meta-analyses and systematic reviews of the research is how teaching and learning with multimedia technology impacts student outcomes in physical education. This area is important because some studies have found that multimedia technology can change teachers’ pedagogic practices from a teacher-centered or teacher-directed model to a more student-centered classroom where students work cooperatively, have opportunities to make choices, and play an active role in their learning. Antoniou, Derri, Kioumourtzoglou, and Mouroutsos (2003), for example, examined the effect of multimedia computer assisted instruction (MCAI), traditional instruction (TI), and combined instruction (CI) on learning rule violations in basketball by university physical education students. Written test results indicated that students in all groups improved their knowledge of rule violations but only those in the TI and CI groups retained this knowledge. Also, the researchers found that TI group showed significantly greater retention than the MCAI group both in the written test and in total performance. In another study that examined changes in physical activity and nutritional patterns of high school physical education students as a result of multimedia technology, Everhart, Harshaw, Everhart, Kernodle, and Stubblefield (2002) found that the year-long multimedia intervention did not affect physical activity or nutritional patterns of students significantly.

Vernadakis, Zetou, Antoniou, and Kioumourtzoglou (2004) reported that MCAI is a functional method in teaching the skill of basketball shooting to middle school students, aged 12 – 14 year old and is as effective as traditional teaching method. The results of this study showed that there were no significant differences between the MCAI, TI and CI groups with regards to the knowledge and skill test. These findings are similar to prior studies that found MCAI to be as effective as TI in teaching tennis (Kerns 1989) and golf rules and strategies (Adams, Kandt, Throgmartin, and Waldrop 1991). Although these individual studies have examined how multimedia technology impacts learning in the cognitive domain, little is known about how this intervention impacts student outcomes in the motor domain.

The effectiveness of physical education software on student outcomes has yet to be determined especially through the use of the newer multimedia programs. Therefore, the purpose of this study was to compare three different instructional methods by means of the knowledge and skill test scores, obtained from three groups of middle school students. The tests assessed the learning of the long jump event. More specifically, the study was conducted to explore the following four research questions:

1. Should one or more items on knowledge test be deleted or revised to obtain a better measure of long jump skill?
2. Do students, on average, report differently on knowledge and skill test using the MCAI, the TI and the CI teaching approaches?
3. Do students, on average, report differently on knowledge and skill test for the pre-test, post-test and 1-week retention test measurements?
4. Do the differences in means for knowledge and skill test between the MCAI, TI and CI teaching method groups vary between the pre-test, post-test and 1-week retention test measurements?

Methods

Participants

To obtain permission for conducting the field experiment, the researchers contacted local middle schools in a northern city of Greece. All school principals expressed their willingness to participate. The private school Dellasal of Thessaloniki, having an indoor gymnasium and essential network equipment, was chosen for the experiment. Forty-eight (n=48) middle school students (25 boys and 23 girls) of seventh and eighth grade, 12-14 years of age (M=13, S.D. =1.01), selected for this study by random sampling method, enrolled in the long jump course. Participants were randomly assigned to one of the three different teaching methods: MCAI (9 boys and 7 girls), TI (8 boys and 8 girls) and CI (8 boys and 8 girls) creating three independent groups of 16 students. All participants had no formal training on learning the long jump event. Prior to group assignments, participants were orientated to the purpose of the study and participant requirements. Following the orientation, informed consent form was obtained from each participant. The students should have returned the informed consent form signed by his/her parent or guardian in order to participate in the research.

Instrumentation

Hardware

Ten 1.8 MHz Pentium IIII class computers equipped with a 17-inch color monitor, CD-ROM, soundcard and small headset, running Windows 2000 professional were used.

Software

The “Asymetrix Multimedia Toolbook” authoring system was used to provide an alternative method of disseminating information to the traditional method approach. This is one of the best-known multimedia software production environments for the Windows platform. A multimedia CD-ROM was produced to administer experimental events including 114 screens; 4 screens were introductory, 1 was main menu, 32 were information, 26 were practice, 40 were feedback, and 11 were help. Material for the multimedia application was taken from a long jump coaching textbook (Jacoby and Fraley, 1995) and modified for this study. The application consisted of three sections: a) history, rules and skill fundamentals b) skill techniques, and c) skill exercises. Two choices menus, one for the termination of the program and one for help, were also included at the bottom of the screen and were always available. The help menu contained a description of the active picture-buttons and suggestions for the program use. The program started with an introductive video of International Association of Athletics Federation (IAAF). The main menu with four active picture-buttons which serve as links to the other screens of the program followed.

The first major section addressed basic knowledge of long jump pertaining to vocabulary used, history of the event, rules, area dimensions, names, and skill fundamentals. The skill techniques section introduced basic techniques of long jump to show jumpers how to avoid common technical flaws. A step by step instructional format that was accompanied by an exceptional graphic simulation depicting proper form of long jump at different stage was included in these sections. A discussion of possible errors, what causes these errors, and what may be done to correct these errors was provided in the description of the skill. When the user had seen enough of the long jump skill, he could supplement short quizzes (multiple choices, true/false) regarding the technique and concepts that were presented. The skill exercises section introduced basic long jump exercises for practical work in terms and levels that were appropriated for beginning long jumper. The exercises section uses video footage of professional long jumpers performing each long jump drill. Each drill was demonstrated several times and was shown from different angles. Audio was used to explain each action and give execution cues to help focus the attention of the user. Common errors, corrections and suggested standards of performance were presented.

Each section included different relevant material like text, sound, pictures, animated vector images, graphics and video. Users were responsible for their own learning, interacting with the material as opposed to passively receiving the information. The interest of the user was thus maintained throughout since they were forced to make choices and were provided with feedback as to decisions made ensuring misconceptions and user problems were answered immediately. Users navigated through the sections by activating the links that appeared on each screen. At the end of the program, a screen with the title of the program, the names of the author and the institution were presented.

Systematic Instructional Design (SID) concept was used to design the multimedia learning material. SID comprises three main phases: a) analysis and planning, b) development and production, and c) evaluation, application and revision, which are discussed in the Appentix.

Knowledge Test

A knowledge test was developed to determine students’ achievement on cognitive learning for the skill of the long jump. A table of specifications was developed to reflect the interrelationship between the identified course content and the levels of learning. Based on these specifications a 20-item, multiple-choice test was constructed. Each test item had five options in order to reduce the probability of guessing. The test construction was based on the linear model which required that the test scores were obtained by summing the number of correct answers with equal weighting over the items. The questions were written on the basis of the learning objectives outlined in the Ministry of Education's Long Jump Curriculum Guideline.

After the questions were constructed as explained above, a panel of experts in long jump teaching and coaching were used to evaluate and judge the content validity of the test instrument. This group reviewed the test items and established whether each item measured the target skill. Every time a set of changes was made, the questionnaire was reviewed again by the consultants, until the instrument was deemed adequate.

The revised version of the knowledge test consisted of a 13-item multiple-choice test. Questions included in the knowledge test fell into one of the following categories: a) eight skill concepts and b) five general rules associated with the skill. A pilot study was performed to access item difficulty and clarity of questions. Questions were scored one point for a right answer and no point for a wrong answer.

Skill Test

No measuring instrument was available to measure the amount of skill development of long jump event but it was not really needed because the results of competitions reflect achievement (Strand & Wilson, 1993). Therefore, a skill test was constructed based on guidelines from a well-established assessing sport skills textbook (Strand & Wilson, 1993). The skill test was developed with two main considerations in mind. First, the test administrators should have been able to administer the test within one class period. Secondly, the testing procedures should have been at a level of understanding not above that of the students. Long Jump area, 30 metre tape measure, scoring equipment and two testers to act as judge and recorder/scorer respectively were needed for the successful completion of the test.

Before the test begins, it was stressed to the students that landing on the feet was important for safety. During the test, the jumper was positioned 6 to 9 metres behind the scratch line. On the "ready, go" signal, the jumper began his approach and accelerated to reach maximum speed at takeoff while gauging his stride to arrive with one foot on and as near as possible to the edge of the board. The jumper used the tuck technique in flight, in which the knees was brought up toward the chest and the legs was brought together for landing. Each student received two warm-up jumps (trials) prior to the actual testing. Students received three test trials. All students performed the first trial before any of the students performed the second trial.

The length of the jump was measured from the edge of the takeoff board to the nearest mark in the landing area surface made by any part of the body. The recorder was responsible to record the results of jumper's effort. The judge was responsible for measuring point of jump and for determining illegal trial in the pit. Trial should be counted as a failure: a) if the jumper started his leap with any part of his foot in front of the scratch line, b) if he run up without jumping or in the act of jumping and c) if he left the landing area after a completed jump and walked back through the landing area. Failed efforts had to be repeated. The test score was obtained by summing the three test trials and dividing that number by the number of the test trials.

Procedure

A pilot study was followed to determine the reliability and validity of the knowledge test. Participants consisted of 24 seventh and eighth grade middle school students. This population was chosen to keep the pilot study similar to the main study regarding participant's age. The method of instruction used for the pilot study was TI, which incorporated a direct style of teaching such as lectures, demonstrations, teacher questions and student questions. Participants were given two 45-minute class periods of instruction and review concerning the long jump event. This was done to take into account the fact that participants had not received formal instruction pertaining to this particular skill for almost one year. The knowledge test was administered on the 3-day on a paper and pencil test consisting of 13 multiple-choice questions. The instruction took place in an indoor gymnasium in order to avoid complications associated with weather conditions.

After the pilot study, a main study was conducted to compare the scores obtained by 48 seventh and eighth grade middle school students for a skill test and a knowledge test. The experimental design consisted of a pre-test, a post-test and an 1-week retetion test for the three of the independent groups. The knowledge test was administered on the 1-day and the skill test was given on the 2-day to measure participant's baseline performance on the selected athletic event. Procedures for the knowledge test were the same as the pilot test. There were three fewer questions, reducing the number of questions to ten.

On the 3-day, ten computers were set up in a blocked-off hallway adjacent to the gymnasium. Each computer had a long jump skill CD-ROM created by the researchers. Computers were separated as much as possible to create individual workstations. Before the experiment started, the MCAI and CI groups were given a 45-minute introductory session on how to use the multimedia application program prepared for this study. Then the physical education instructor gave a 45-minute lecture to all participants introducing the unit of long jump event. Instruction, practice, and testing for this study were held on ten separate and successive weeks. The groups met for 45-minute, 1 times each week in an indoor gymnasium.

The TI method incorporated a direct style of teaching including lectures, demonstrations, teacher questions and student questions. Participants in the TI group received a series of progressive skills, performed in drill format, accompanied by verbal feedback in the form of positive reinforcement. Students were given verbal instruction for 15-minute as well as 15-minute of practice time following the formal instruction time. They were allowed to work alone without a partner. The physical education instructor gave verbal instruction before every drill and knowledge performance every five trials during the 15-minute of practice time. There were 5-minute of warm-up at the beginning of the period and the remaining time of approximately 10-minute was for cool-down and review.

Participants in the MCAI group were allowed to work independently. The students were given 15-minute of computer time on a Pentium IIII computer. A multimedia program was developed for the purpose of this study, which was based on hypertext, graphics, animation, media and video. The MCAI program consisted of three sections, which corresponded precisely to theoretical and practical work. Students received 15-minute of physical practice time following the time spent on the computer. There were 5-minute of warm-up at the beginning of the period and the remaining time of approximately 10-minute was for cool down and review. The instructor was present for organization and management supervision only. No verbal or visual reinforcement of any kind was offered by the instructor.

The CI group followed the same procedure, while implementing both the multimedia program and the traditional instruction. In the first five weeks the students participated with the TI method group, and the remaining weeks with the MCAI method group. The theoretical and practice sessions consisted of the same instruction and exercises, which took place in the MCAI and the TI methods. Material for the three method groups was taken from a long jump coaching textbook (Jacoby and Fraley, 1995).

At the end of the treatment, the knowledge was given and the following day the skill test that previously served as a pre-test was given to students as a post-test. One week later, the same procedure was repeated on the 1-week retention test to measure the level of retention in the selected athletic event. During the experiment, the participants in the three groups had no access to multimedia or to traditional learning environments beyond what was utilized as part of the experiment.

Design

Due to practical limitation, a field experiment instead of a laboratory experiment was conducted to test the research questions. The experiment was a factorial design with teaching method groups (MCAI, TI and CI) and repeated measurements (pre-test, post-test and 1-week retention test) as independent variables, and knowledge learning and skill learning performance as dependent variables.

Results

Homogeneity of variance and Sphericity was verified by the Box's *M* test, the Levene's test and the Mauchly's test (Green & Salkind, 2003). Initial differences between the three groups for the mean knowledge and skill test scores were tested using one-way analysis of variance. An item analysis using the responses of the pilot study was conducted to determine the difficulty rating and index of discrimination. In determining the internal consistency of the knowledge test, the alpha reliability method was used. Two-way analyses of variances (ANOVAs), with repeated measures on the last factor, were conducted to determine effect of method groups (MCAI, TI, CI) and measures (pre-test, post-test, 1-week retention test) on knowledge and skill test. We controlled for family wise error rate across these tests using Bonferroni approach, which means that the alpha level of significance was set to .025 (.05/2). Means and standard deviation for the MCAI, TI and the CI group in pre-test, post-test and 1-week retention test are presented on table 1, while results of each analysis are presented separately below.

Table 1. Means and standard deviations for pre-test, post-test and 1-week retention scores of the three groups on knowledge and skill tests.

	Group	N	Mean	Std. Deviation
Knowledge Pre-test	TI	16	3.43	1.19
	MCAI	16	3.69	1.25
	CI	16	3.94	1.57
Knowledge Post-test	TI	16	5.95	2.02
	MCAI	16	6.25	2.24
	CI	16	6.56	2.31

Knowledge 1-week retention test	TI	16	5.89	1.98
	MCAI	16	6.13	2.06
	CI	16	6.50	2.28
Skill Pre-test	TI	16	2.94	0.27
	MCAI	16	2.69	0.53
	CI	16	3.00	0.47
Skill Post-test	TI	16	3.42	0.27
	MCAI	16	2.91	0.53
	CI	16	3.59	0.48
Skill 1-week retention test	TI	16	3.37	0.28
	MCAI	16	2.84	0.53
	CI	16	3.55	0.48

Item Analysis

The pilot study knowledge test had a mean difficulty rating of 59%. When all items were analyzed, two questions, or 15.38% of the items, had unacceptable difficulty rating values. The utilization of a difficulty rating criterion of between 10% and 90% resulted in 84.61% of the items yielding an acceptable level of difficulty. The pilot study knowledge test had a mean index of discrimination of .36. When all items were analyzed, three questions, or 23.07% of the items yielded an unacceptable index of discrimination values. The acceptable value for index of discrimination was .20 or higher. Acceptable index of discrimination values were observed for 76.92% of the items. Finally one more question, or 7.69% of the items, had unacceptable index discrimination and difficulty rating values. As indicated by the information in table 2, three of the items (7, 12 & 13) were therefore deleted from the test for the main study.

Table 2. Summary of Item Analysis for pilot study knowledge test.

Questions	Index of discrimination	Difficulty rating	Results
1	.60	30%	Retained
2	.48	35%	Retained
3	.30	79%	Retained
4	.55	37%	Retained
5	.48	75%	Retained
6	.39	54%	Retained
7	.08	78%	Eliminated
8	.29	64%	Retained
9	.33	59%	Retained
10	.60	27%	Retained
11	.57	35%	Retained
12	.03	97%	Eliminated
13	.04	96%	Eliminated

Reliability Analysis

An alpha reliability coefficient .76 was computed based on the inter-item correlation coefficients of the pilot study knowledge test. According to Green, & Salkind (2003), the reliability coefficient should be at least .70 for the test to be considered reliable. Thus, the determination was made that the pilot knowledge test was a reliable measuring instrument.

Two-way Analyses of Variances (ANOVAs) with Repeated Measures

Knowledge Test

There were no significant initial differences between the three teaching method groups for the mean knowledge test scores, $F(2,45) = 1.696$, $p>.05$. Mauchly's test of Sphericity was significant so a lower-bound (=0.500) transformation for the degrees of freedom was applied. A significant main effect was noted for the time, $F(1,45) = 100.037$, $p<.001$ but not for the group, $F(2,45) = 1.453$, $p>.05$, while the interaction time X group was also not significant, $F(2,45) = .460$, $p>.05$.

Difference and repeated contrasts were conducted to follow up the significant time main effect. Differences in mean rating of knowledge test in TI group were significantly different between pre-test and post-test, $F(1,15)_{=}$ 53.571, $p<.001$ and between pre-test and 1-week retention test, $F(1,15)_{=}$ 77.143, $p<.001$. Differences in mean rating of knowledge test in MCAI group were significantly different between pre-test and post-test, $F(1,15)_{=}$ 17.921, $p<.001$ and between pre-test and 1-week retention test, $F(1,15)_{=}$ 21.593, $p<.001$. Finally differences in mean rating of knowledge test in CI group were significantly different between pre-test and post-test, $F(1,15)_{=}$ 39.611, $p<.001$ and between pre-test and 1-week retention test, $F(1,15)_{=}$ 41.667, $p<.001$. As shown in figure 1, the post-test and 1-week retention test knowledge scores were remarkably greater than pre-test knowledge scores for the three groups, while the difference between the post-test and 1-week retention test was not significant.

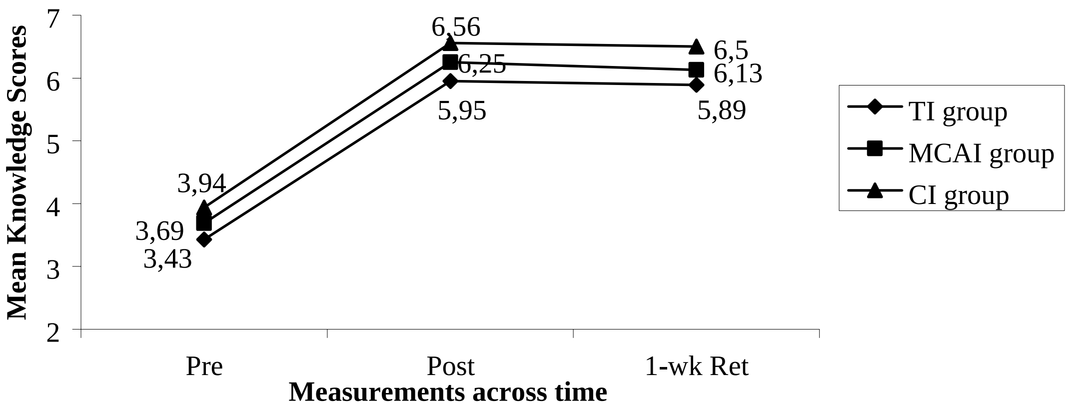

Figure 1. Performance of the three groups on all measurements across time of the Knowledge Test.

Skill Test

There were no significant initial differences between the three teaching method groups for the mean skill test scores, $F(2,45) = 2.37$, $p>.05$. Mauchly's test of Sphericity was significant so a lower-bound (=0.500) transformation for the degrees of freedom was applied. A significant main effect was noted for the time, $F(1,45) = 1986.27$, $p<.001$ and for the group, $F(2,45) = 7.30$, $p<.01$, while the interaction time X group was also significant, $F(2,45) = 149.45$, $p<.001$.

One-way analysis of variance (ANOVA) was conducted to follow up the significant interaction and assess differences among teaching method groups at each time period. Significant differences among the groups were noted in both post-test ($F(2,45) = 10.31$, $p<.001$) and 1-week retention test ($F(2,45) = 11.08$, $p<.001$). According to Scheffé pairwise comparisons, at post-test, the mean skill test scores for the MCAI group (M=2.91 SD=0.53) was significantly lower than mean skill test scores of the TI (M=3.42 SD=0.27) and CI groups (M=3.59 SD=0.48). Similarly, at 1-week retention test measure, the mean skill test scores for the MCAI group (*M*=2.84 *SD*=0.53) was significantly lower than mean skill test scores of the TI (*M*=3.37 *SD*=0.28) and CI groups (*M*=3.55 *SD*=0.48). As shown in figure 2, the difference in mean skill test scores was lower for the MCAI method group at post-test and 1-week retention test measures.

Finally, difference and repeated contrasts were conducted to follow up the significant time main effect. Differences in mean rating of skill test in TI group were significantly different between pre-test and post-test, $F(1,15)_= 9.304$, $p<.001$ and between pre-test and 1-week retention test, $F(1,15)_= 15.016$, $p<.001$. Differences in mean rating of skill test in MCAI group were significantly different between pre-test and post-test, $F(1,15)_=$ 23.710, $p<.05$ and between pre-test and 1-week retention test, $F(1,15)_= 19.286$, $p<.001$. Finally differences in mean rating of skill test in CI group were significantly different between pre-test and post-test, $F(1,15)_= 24.771$, $p<.001$ and between pre-test and 1-week retention test, $F(1,15)_= 25.312$, $p<.001$. As shown in figure 2, the post-test and 1-week retention test skill scores were remarkably greater than pre-test skill scores for the three groups, while the difference between the post-test and 1-week retention test was not significant.

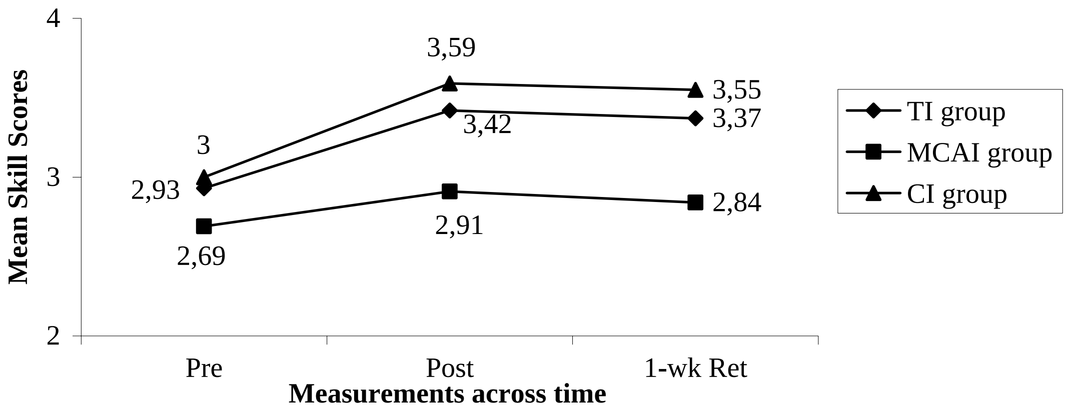

Figure 2. Performance of the three groups on all measurements across time of the skill test.

Discussion

The present study was designed to examine differences that may occur when individuals learn a motor skill under different instructional teaching methods and replicated previous findings by showing differential performance dependent on teaching methods. With regard to the knowledge and skill test, all groups improved their cognitive learning and skill development in long jump event, after instruction. Post-test results indicated no significant differences between the groups concerning the written test. Nevertheless, the mean skill test scores of the TI and CI groups were significantly greater than MCAI group. Retention test results showed that groups retained the knowledge and skill learning. However, the mean skill test score of the MCAI group was significantly lower than the TI and CI groups.

Comparison to the literature

The results from this study were parallel with the results reported in the literature. Some evidence suggests that the TI method is superior to the MCAI method while other evidence is contradictory. From a recent multimedia study on learning rule violations in basketball, Antoniou et al. (2003) found that university physical education students receiving lecture instruction performed significantly better than the MCAI group. In other literature reported, the MCAI method was found to be superior. Siskos, Antoniou, Papaioannou, and Laparidis (2005) found that MCAI was superior to traditional classroom teaching in the transmission of health-related fitness and nutrition knowledge. Also, others report no significant differences in a comparison of testing results between TI and MCAI methods. Vernadakis, Zetou, Avgerinos, Giannousi and Kioumourtzoglou (2006) compared three different instructional methods by means of the skill test scores, obtained from three groups of middle school students. The tests assessed the learning of the setting skill in volleyball. They reported equal improvement in learning with TI, MCAI and CI method. Furthermore, they conluded that the combined method of instruction tended to be the most effective for skill development. In earlier studies comparing the impact of MCAI and TI method, Adams, et al. (1991) and Kerns (1989) found no significant differences in scores of tests in golf and tennis rules.

Discussion possible shortcomings of the design

Evaluating the outcomes of the present research study, greater consideration needs to be given to those factors that might strongly affect students' learning. First, students were from one middle school of Thessaloniki. A larger and more diverse sample would provide a more stringent test for cognitive learning and skill development on a MCAI program. Additionally, the results reported in this study are based on a single MCAI program. This is a case-specificity problem. It is possible that a different type of MCAI package covering different content would yield different results.

Secondly, the age of students might be critical when it comes to learning independently. Since the participating students were all around 13 years of age when this study was conducted, they might not possess the learning skills that are needed in order to work independently using individual computers. Besides, research has also found that first-time users of computers are often overwhelmed by the vast amount of materials and information that can be presented by multimedia courseware (Renshaw and Taylor, 2000). These types of differences between the three groups, therefore, might be reflected in the students' post-test and 1-week retention test skill scores.

Third, no attempt was made to control possible differences in computer skills and multimedia experiences of the students or the effective learning time of the students' real engagement in multimedia learning. If these limitations have been controlled and the effective learning time had lasted longer, the researchers might have reported more precise results for the effectiveness of MCAI, TI, and CI methods on cognitive learning and skill development of the long jump event. For those reasons, further research may be needed to replicate this study.

Another consideration for the results includes time limitations on instruction and use of the multimedia program. With respect to time factors, participants who were in the TI group did not have to concern themselves with logging on to a multimedia computer program, navigating within that program and pacing their progress so as to remain within the 15-minute of practice time.

Finally, the TI group did not have to face the unknown instructional environment of computers, since elementary school students have experienced classroom instruction for roughly 6 years. The MCAI method, according to McKethan, Everhart, and Stubblefield (2000), has the disadvantage of requiring prior experience of the educational process from the user. In the present study the unknown instructional environment of computers did directly affect the improvement of motor learning in MCAI group.

Those limitations of the research learning environment may have significantly affected the experimental groups' ability to learn and to retain the cognitive and motor skill of the long jump event. However, it would be difficult to be certain, that the MCAI group would have been more successful than TI and CI groups on cognitive learning and skill development if the above limitations could have been eliminated. In that sense, these results indicate that students can be taught through the use of multiple effective teaching techniques. Multimedia programs have been generally successful especially when it has been used in connection with regular classroom instruction (Vernadakis et al., 2004).

Consequences for future research

In conclusion, multimedia programs can be utilized to enhance the effectiveness of teaching strategies or techniques in physical education classes. Computers can be used for the teaching of the cognitive aspects of sports such as rules and scoring procedures, and to allow teachers to have more time to spend with students' motor skills. However, these conclusions are limited for students aged 12 – 14 years old. More studies should be conducted to investigate the effect of MCAI in different ages and for various sport activities. Also, it is critical to continue researching into how students learn in different technological environments, since the researchers have only begun to explore the uses and practicality of MCAI.

Consequence for future practice

Education today is experiencing a variety of problems such as budget cuts and large class sizes, and teachers are being seriously affected by these problems. Teachers must find new and better ways to facilitate the learning of students. For example, physical education classes can be divided, one group working with software programs such as computer assisted instruction, while the other group can be at the gymnasium or at a teaching station, learning the motor skills involved in the sport. Teachers would have more engaged time with each student because the group would be small. Therefore, physical education teachers and teachers in general have to take full advantage of the new technology such as multimedia programs. It is of up most importance to educate teachers and provide them with opportunities to build new teaching strategies which incorporate the use of computer and advanced technologies.

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Appendix

Systematic Instructional Design (SID) concept was used to design the multimedia learning material. SID comprises three main phases: a) analysis and planning, b) development and production, and c) evaluation, application and revision, which are discussed in following paragraphs.

Phase 1: Analysis and planning

Learner characteristics is one of the most important factors effecting the design of multimedia learning material. Specifically, it seems necessary to examine the level of prior knowledge that the learners have on the subject. If the learner has prior knowledge, it is easier to integrate the new knowledge into the existing knowledge structure and decide on meaningful learning steps in the instructional tool. In addition, the age and maturity of the users are other important aspects to be considered. First, the users who participated in this study had no previous knowledge on the unit selected for the study. The students took an athletic course in the previous semester, but it did not include the selected units. Second, the researcher consulted four subject-matter experts (one university instructor and three physical education instructors) about the participants' age and maturity level and concluded that the unit selected for the study would be appropriate for this group of students.

The objectives of the unit covered in the instructional material were determined on the basis of the Ministry of Education's Long Jump Curriculum Guideline.

Content analysis was conducted and concepts, interrelated concepts, and procedures were determined on the basis of the objectives of the unit determined. Systematic relationships between the concepts were organized. A subject-matter expert evaluated the semantic relationships of the concepts determined. In the light of this evaluation, the semantic relationships between the concepts were reorganized.

Considering the characteristics of the users and unit, Ausubel's deductive learning strategy was adapted. First general and simple knowledge was provided, then detailed and specific knowledge.

Finally, the issues of knowledge organization and linking nodes to each other were managed. Hierarchical links were used in that material. First basic concepts, and then subordinate concepts related to the basic concepts were presented.

Phase 2: Development and production

Concept maps of the unit were constructed to ascertain interrelations between concepts determined in content analysis. That stage was important to show each node and links between the nodes.

Story boarding was the last step before the programming stage. Story boarding involves showing each navigation window on a page. Each window to be designed in this study was shown on a separate page. Active keys, the names of linked windows, links, text, visuals, video, sound, and graphics were also shown on that page.

“Asymetrix Multimedia Toolbook” authoring system was used for programming.

Phase 3: Evaluation, application and revision

After the material was developed, the researchers gave it to an instructional technology specialist, a subject-area expert, and three subject area teachers for evaluation. Researchers revised and improved the material according to the feedback received from those experts.

On a First Attempt to Modelling Creativity Learning by Means of Artificial Neural Networks

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Abstract

The contribution presents some first results concerning the usability of neural network, obtained from field based study that dealt with children's creativity learning in games. The first question was whether the time series of learning success could be analysed using conventional Kohonen Feature Maps (KFM) in order to find and distinct types of time-dependent learning patterns. The second question was whether the neural network could be used for simulating those learning processes – in order to eventually schedule and optimize those processes individually. The first problem could be solved using Dynamically Controlled Networks (DyCoN: Perl, 2004), which is a KFM-derivate that is able to learn continuously. A number of types of learning patterns could be found which seem to be characteristic for specific learning behaviours. In order to solve the second problem, the concept of DyCoN had to be completed by some properties of "natural" learning: One aspect was to dynamically adapt the capacity of the network to the requirements of the learning process. This could be done by integrating the concept of Growing Neural Gas (GNG: Fritzke, 1995).

Another aspect was to take care of seldom events of high relevance – as creative activities are –which are neglected by all known net approaches. The result is the Dynamically Controlled Neural Gas (DyCoNG: Bischof, 2006; Gerharz, 2006) the concept of which completes the combination of DyCoN and GNG by quality neurons that reflect the quality of information and therefore can measure the creativity of a recorded activity. Initially results from DyCoNG-based simulation show that the network is able to reproduce recorded learning processes and separate main process types.

KEYWORDS: LEARNING, CREATIVITY, NEURAL NETWORKS, SIMULATION

Methods

Tests design and data recording

The creative learning model used data from a BISp-sponsored project (VF 0407/06/04/2005-2006). 42 children of around seven years of age participated in the field study. The children who were undergoing a non-specific treatment attended the standardized training program by Roth (2004).The task was to recognize gaps in a defence line for passing the ball (cf. Memmert & Roth, 2003). Over a period of 6 month, every two weeks the children's actions were video-recorded, and the player positions were extracted from the video frames. Subsequently, the actions were rated regarding originality and flexibility using the original frames (including context information from the game) as well as using standardized computer-simulated frames (see Figure 3, graphic bottom right).

Net-based modelling of creativity

An action in a specific situation is called creative or of high originality if it is a seldom event in that situation. In terms of networks, the regarding stimulus has a great distance to all stimuli the network has already learned, and therefore – from the information-theoretic point of view – has a high relevance. Conventional KFMs, however, do not care about great or small distances but melt the new stimulus to the best fitting neuron – therefore neglecting the particularity of that specific information. In contrast, DyCoNG embeds every neuron in a sphere that limits its area of attraction. New stimuli outside the spheres of all available neurons are categorized as "strange" and then define new (quality-) neurons of high relevance. This specific quality of information-theoretic relevance can fade out if the same stimulus is fed more frequently to the net, resulting in a slowly opening for different stimuli and therefore eventually merging into different neurons and clusters (see Figure 1). If in turn a neuron is less frequently contacted compared to its neighbourhood it again can become an isolated quality neuron with high relevance.

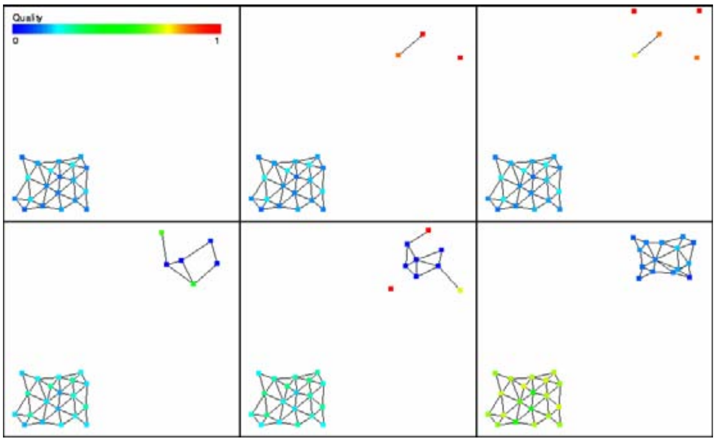

Figure 1: An existing network (top left) is completed by some quality neurons that represent relevant information (top middle and right). After some steps of activation, the new neurons loose their quality: they drift and merge into a new cluster (bottom left and middle) until finally the new cluster has less relevance than the old one (bottom right; the colour of the old cluster has changed from blue to light green, indicating an increase of relevance compared to the meanwhile blue new one).

Net-based analysis and simulation

Two kinds of net-based analysis were carried out:

The first approach was to analyse the time-depending learning profiles (see Figure 2) under the aspect of similarity. This was done using a conventional KFM, where the profiles were fed into as patterns, which then were recognized as members of clusters respectively types of learning behaviour (see Figure 4).

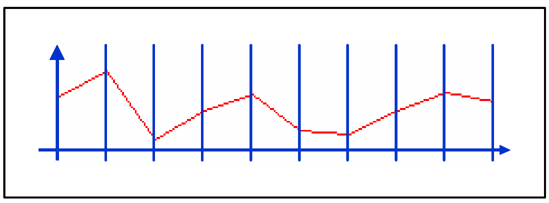

Figure 2: Example of a learning profile, i.e. a time series of creativity values

The second approach was to simulate the learning process itself using a DyCoNG, with the original data as input and learning profiles as output (see Figures 3 and 6). The idea was that the originality or creativity of an action can be described by the quality of the representing neuron: high creativity goes with low frequency and high neuron quality values and vice versa. Figure 3 shows a red neuron of high quality, representing an action of high originality.

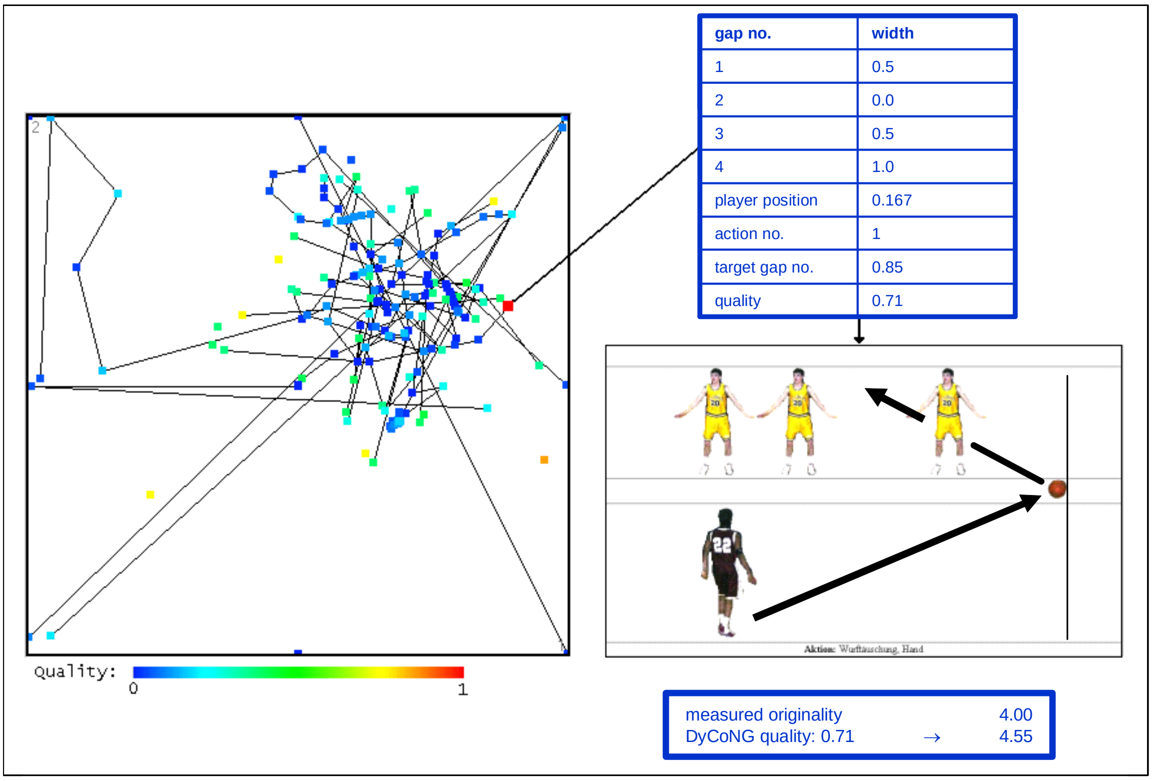

Figure 3: 2-dimensional projection of a trained DyCoNG together with the reconstruction of the action-data represented by the red neuron.

The learning profiles resulting from DyCoNG-training were compared to the regarding rater-evaluations as well as to the learning types obtained from the children's profile analysis.

Results

KFM-based test analysis

The obtained 42 learning profiles (see Figure 2) were tested on the trained net. The resulting entries show clusters of activated neurons, which build a collection of 9 types representing the individual profiles, 7 of which are significant for type definition (see Figure 4).
Those 7 types show relevant differences and were used for further investigations: Overlaying those profile types smoothing approximations results in a sequence of prototypes that ranges from super-compensation-like behaviour over linear increase to something like inverse super-compensation, where the learning success first was increasing and afterwards decreasing (see Figure 5).

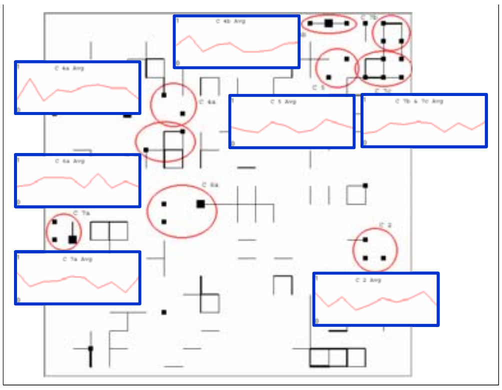

Figure 4: Trained network with marked clusters of neurons representing typical profiles.

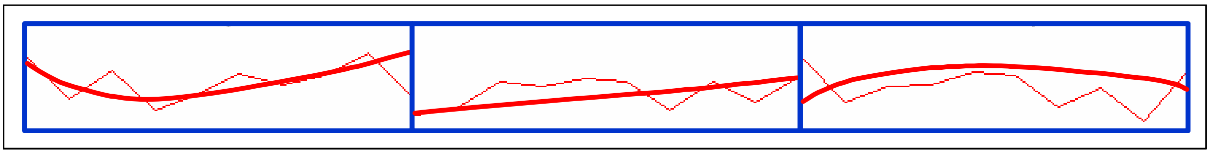

Figure 5: Three characteristic prototypes of learning behaviour, ranging from super-compensation over linear increase to inverse super-compensation.

DyCoNG-based simulation of learning processes

In order to check whether the net-based neuron quality meets the measured action originality the time-specific data sets of the children (i.e. the training stimuli for the net) were classified into three classes: The (red) class of high originality (values 6 and 5), the (green) class of medium originality (values 4 and 3), and the (blue) class of low originality (values 2 and 1). Training the net with stimuli from the respective classes and taking the mean quality values of the corresponding neurons results in specific time series representing the learning behaviour of the net with regard to the particular class. As can be seen from Figure 6 (left graphic), the plotted profiles are not only similar to those from children's learning but also are separated regarding the levels of originality. Moreover, there seems to be a certain qualitative correspondence between the simulated and the original profiles (Figure 6, right graphic) – which however has to be taken with care because of significant differences regarding the quantitative aspects and the need for deeper analyses and interpretation.

Conclusion

It could be demonstrated that networks can be helpful for classifying types of creativity learning, which can support a more individual adaptation of training programs to athletes. First preliminary result from learning process analysis could be confirmed (Memmert & Perl, 2005). Additionally, a first step has been done in order to simulate learning behaviour by means of networks, which can be helpful for optimizing individual training processes. More future work is necessary in order to analyse more data and improve the simulation techniques.

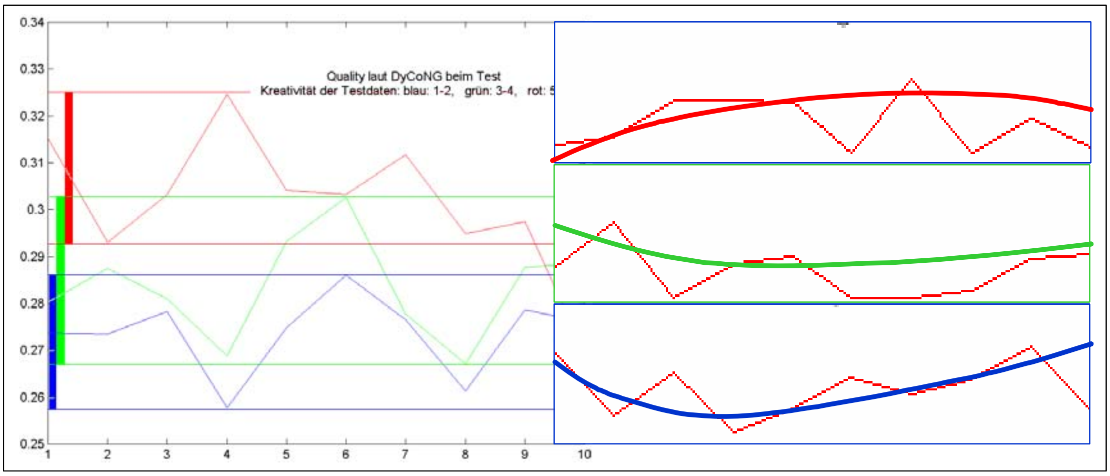

Figure 6: Profiles of mean quality values corresponding to the originality classes high (red), middle (green) und low (blue), compared to corresponding types of original learning profiles.

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Interaction in Games: Qualitative Analysis by Means of the Load-Performance-Metamodell PERPOT

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KEYWORDS: HANDBALL, INTERACTION, PERPOT

Introduction

The dynamics of team behaviour in games shows rather inhomogeneous distributions of the levels of activity and effectiveness, where phases of great effort are followed by phases of reduced activities, which are used by the opponent team for increasing its pressure. Lames (Lames, 2006) measured the scoring effectiveness depending on the aggregated numbers of ball possessions that formed a non-linear transformation of the time axis. The results were diagrams like that in Figure 1, where high respectively low performance intervals of both of the teams can alternate, follow and overlap each other or even can appear concurrently, as is marked by the segments A to E.

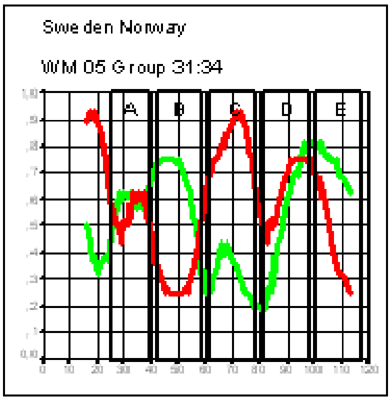

Figure 1. Lames' analysis of handball.

Based on the interpretation that the subsequent effectiveness of the one team is a kind of performance, which in a delayed way is caused by the past and present pressure or load from the opponent team – i.e. its activities and scoring – the game can be understood as a symmetric process of load-performance-interaction. Such symmetric feed-back-systems very often show an oscillating-circuit-behaviour, where both components show oscillations that are in anti-phase to each other (see segment B in Figure 1).

Therefore a white-box-approach has been used for modelling, where two exemplars of PerPot (Performance Potential Metamodel, which originally was developed in order to analyse physiological adaptation processes, see Perl (2005)) model the respective dynamics of each team:

On the internal level the team-specific dynamics of performance depending on fatigue and recovery have to be modelled.

On the level of interactive feedback the output of the one team serves as input for the other team. Here e.g. scoring or pressure can cause positive effects like motivation and increased effort or negative effects like frustration and giving up.

On the level of external control tactical or strategic aspects can determine, influence, or modify local as well as global behaviour.

Model design and dynamics

Briefly spoken, the behaviour of PerPot is determined by the relation of the delay DR of the positive response flow and the delay DS of the negative strain flow (see Figure 2), which together form the antagonistic dynamics. Moreover, time-dependently varying delay values can effect as well the values of performance as the time needed for transferring the recovered response potential (RP) to performance (PP).
Those dependences are reasons for a PerPot-based modelling of the team-internal dynamics: Different from the standard PerPot dynamics with constant delay values the modified "team-PerPot" contains connections between internal potentials SP and RP and the corresponding delays DS and DR. In particular in the case of RP and DR this means: increasing response potential indicates improving recovery and therefore reduces the delay for sped up reaction.

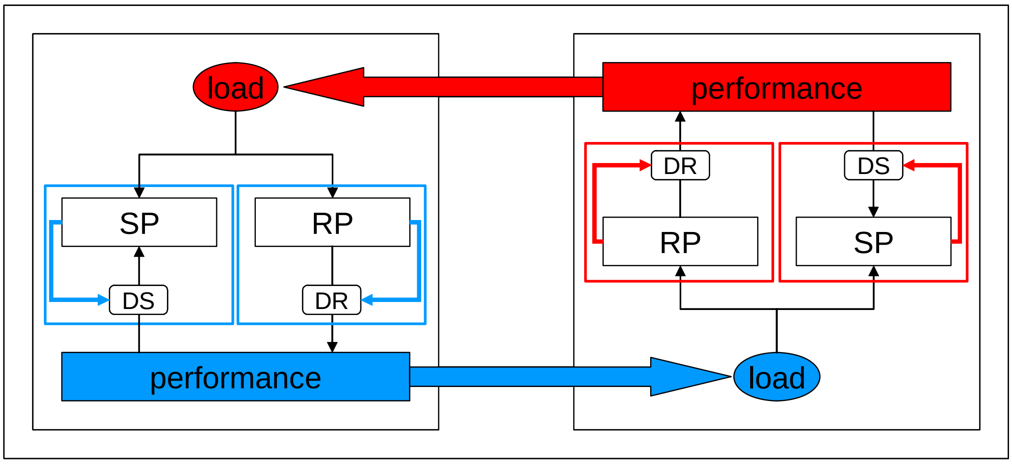

Figure 2. Two exemplars of PerPot with internal potential-delay-control, connected by feed back flows, where the performance output of the one model builds the load input of the other model (see Perl (2005)).

The feed back connection of two exemplars of PerPot (each one representing one of the teams) immediately results in a remarkable behaviour (see Figure 2 and Figure 3): After a small initial phase of balancing in, the performance profiles of the two connected team-PerPots oscillate in a rather perfect periodicity – without any external impact, and just depending on different team-specific start-parameters that determine the minimum values.
However, the aim is not to generate a periodical behaviour, but – in contrast – to simulate oscillating but non-periodic behaviour as is given by the original handball data.
In terms of dynamics and control the result from Figure 3 means that under constant conditions, i.e. without external impact, the oscillation will continue unlimited. Those external impacts can come from the trainer or from the players and can consist of decisions like "go slow and recover" or "stop recovery and start to react". These effects can be understood as slow down or speed up of the mechanism described above, and therefore can be modelled by delays that briefly can be described as "gradually closing the valve" or "gradually opening the valve". In the following these external impacts are called "external delay of reaction".

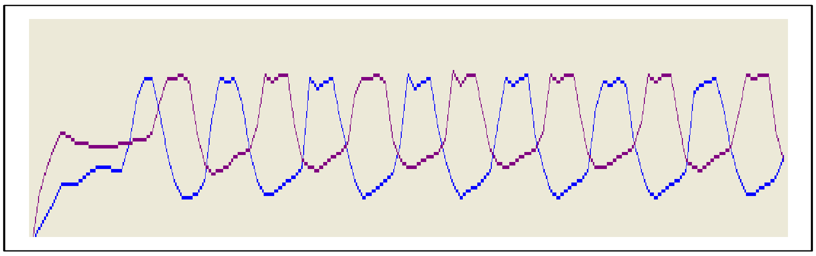

Figure 3. Oscillating behaviour of two PerPots connected to a feed back circuit.

The left graphic of Figure 4 shows the example from Figure 3, where both teams have identical constant external delays of reaction. In the second graphic the red team has a still constant but greater external delay, resulting in a reduced frequency for both teams. This is because a delayed reaction of the one team in turn shifts the reaction of the other team. Finally, in the right graphic, the effect of changing the external delay is shown: The periodicity becomes disturbed but after a while is restored again. Moreover, also the amplitudes are changed. These results suggest that the external delay not only plays the role of frequency but also influences the amplitude and therefore encourages for taking those external delay of reaction as the only controlling parameter, while the connected PerPots are working autonomously if they have once got those external control values.

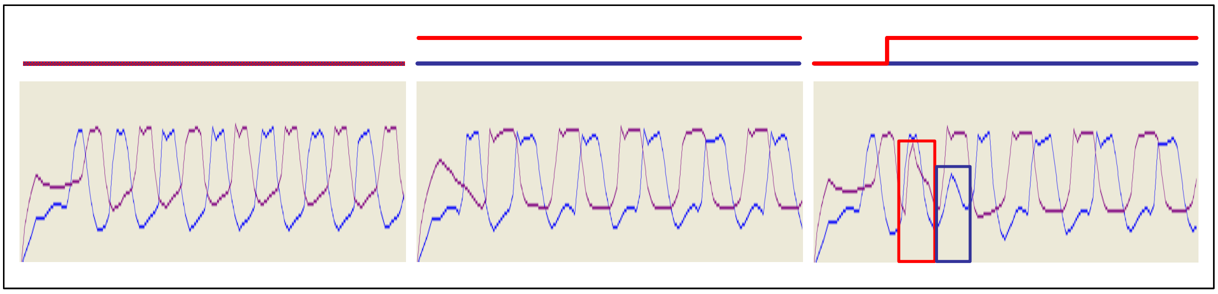

Figure 4. Oscillations depending on the respective values of the external delays of reaction (red and blue lines on top).

This concept allows for simulating given behaviours as well as for scheduling desired ones by just modifying those profiles of external delays of reaction.
Therefore, it has to be understood how a change of external delays can change frequencies and amplitudes of the resulting performance profiles: A small external delay of reaction means a short recovery phase. The internal response potential is not optimally filled, and therefore the transfer to performance yields only rather small amplitude. I.e. small external delays can cause higher frequencies together with smaller amplitudes. In turn, large external delays can cause lower frequencies together with greater amplitudes.

Results

In Figure 5, two games of Germany haven been analysed exemplarily: In the first game against Denmark, the German team shows two long phases of large delay of reaction with respectively corresponding maxima of performance. In contrast, the Danish team shows smaller delays that cause comparably small fluctuations of performance. In so far, this example confirms the ideas developed above.
In the second game the Croatian team plays more or less the role of Germany from the first example: Large external delays cause comparably high performance. In contrast, the German team shows smaller delay values, which however are not as small as those of Denmark. The

result is a German performance profile, which lies between those of Denmark and Croatia and the frequency of which is smaller than that of Denmark.

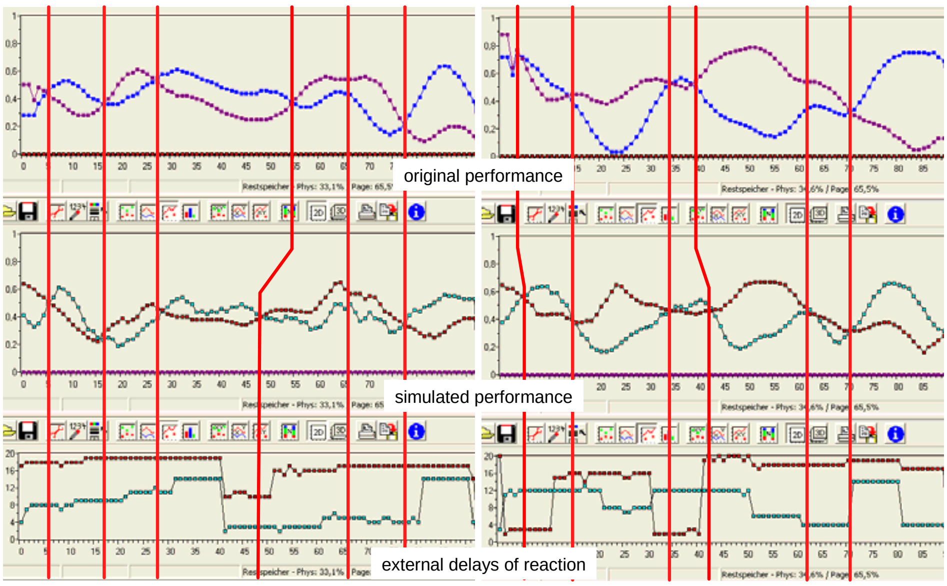

Figure 5. Left: Germany (red) vs. Denmark (blue) (22 : 20). Right: Germany (blue) vs. Croatia (red) (23 : 23).

Summary and Outlook

The PerPot-based model seems to work quite well and enables a satisfying simulation. This result is not only satisfying in principal: If measuring the behavioural indicators of a team in a game (e.g. performance or tactics), normally the measure is not an absolute but a relative one – i.e. the number of successful activities of the one team partially depends on the behaviour of the opponent team. In contrast, the presented model allows for exposing the profiles of external delays of reaction, which – regarding to the current game – are indicators that specifically characterize the respective teams. It therefore makes sense to analyse those profiles of reaction under the views of inter- and intra-individual stability and similarity – i.e. if there are opponent-independent patterns (invariants) or opponent-specific patterns (tactical variability or strategic concepts).

The question remains, however, whether such a model can help for understanding real behaviour in detail: If the "physiologic state" of a team together with the processes of fatigue and recovery characterize the internal dynamics of the interaction, then the concept of antagonism of the PerPot-approach fits, and the results become interpretable. In this case the behaviours of the teams become understandable and therefore enable for developing strategic plans. Otherwise first the characteristic dynamics has to be recognized and then analyzed whether it is compatible with the PerPot-concept.

At any case, the advantage of the approach could be to predict up-coming weak phases earlier and control and optimize the activities of a team under a strategic point of view.

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Training- and Contest-Scheduling in Endurance Sports by Means of Course Profiles and PerPot-based Analysis

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KEYWORDS: ENDURANCE SPORTS, GPS, ALTIMETRY, SCHEDULING, PERPOT

Introduction

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

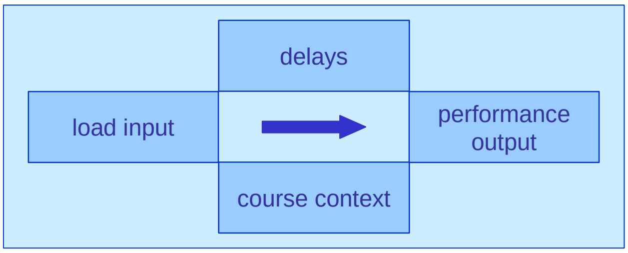

Figure 1: Load-performance-interaction depending on physiologic delays and course context

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

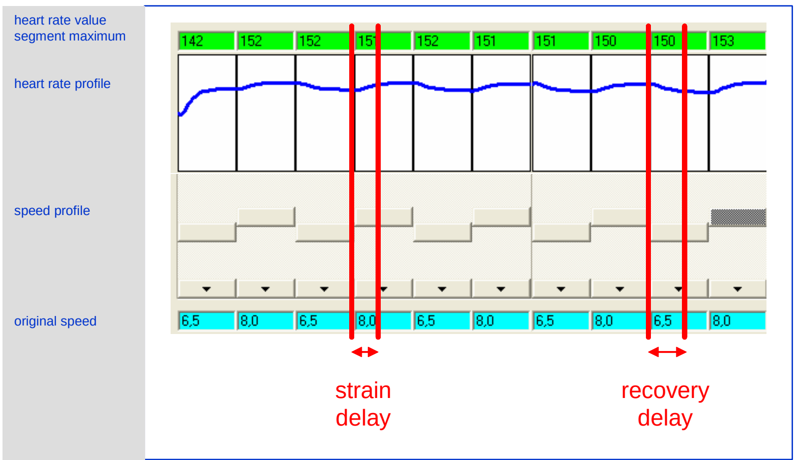

Figure 2: Delayed influence of strain and recovery in case of speed changes (also see explanations in the text). The marked delay intervals exemplarily indicate the time needed until stabilizing after a speed change. The figure shows the standard case that the recovery delay is larger than the load delay.

Figure 3 demonstrates, for the example of a periodic height profile (graphic on bottom), that the slope-caused load can affect the heart rate profile (graphic in the middle) more than the speed-cause load does (graphic on top). The red arrows mark phases of inverse profiles, while the green arrows mark phases of equal tendencies.
All examples are calculated on the basis of original data using the PerPot-derivate "SpeEdi Run".

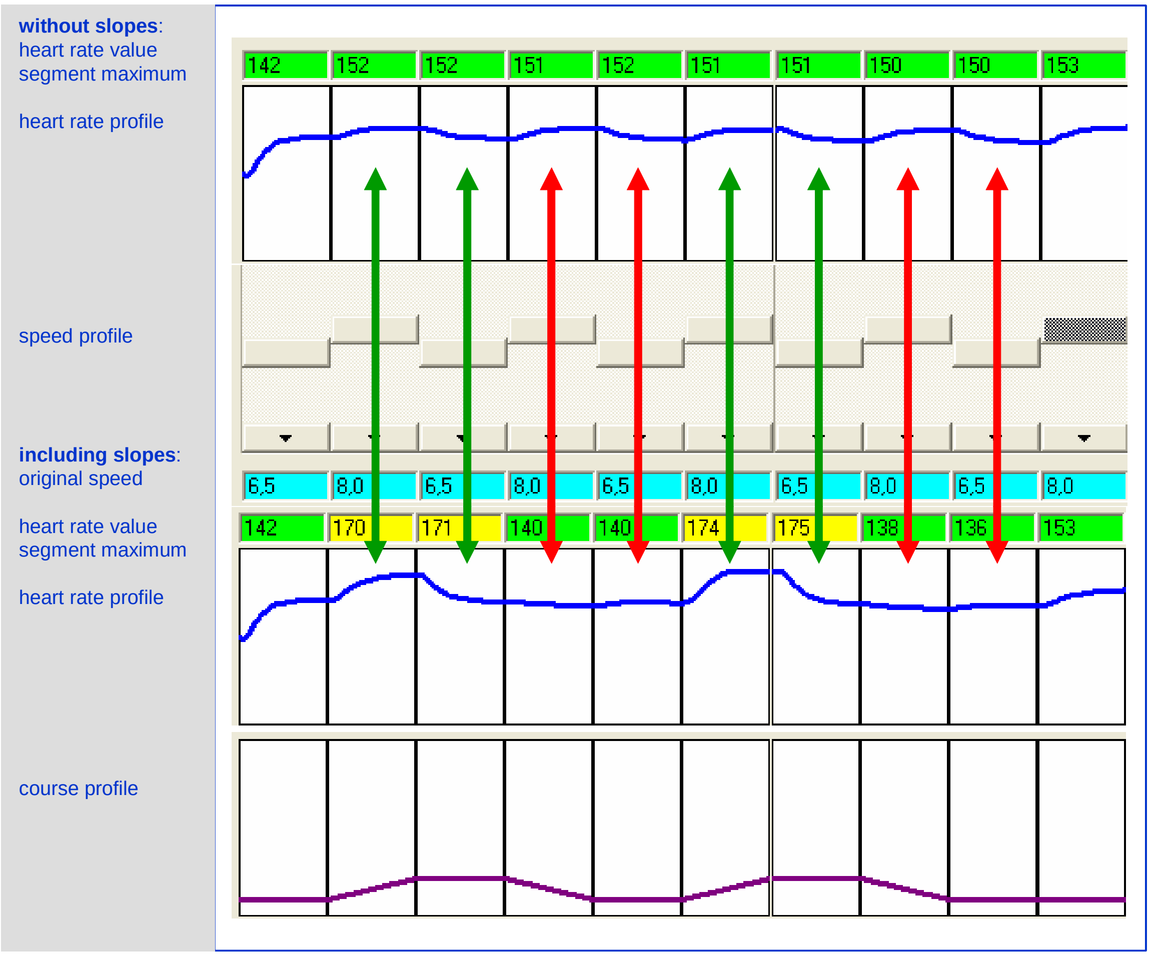

Figure 3: Heart rate profile caused by speed changes only (graphic above) compared to a profile that additionally is influenced by slope changes (graphic below) (also see explanations in the text)

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

Methods

Load-performance-interaction can be analyzed by means of the tool "SpeEdi Run" that was derived from PerPot (see Perl, 2005), where speed is taken as load input and heart rate is taken as performance output. Additional impact parameters are taken from the course profile, in particular from the positive and negative slopes:
Depending on the original speed v_0 and the original slope S, a transformation $vR = \lambda(S,v_0)\times v_0$ calculates a (virtual) reference speed v_R that represents the load effect regarding the resulting heart rate output. Each v_0 defines a characteristic λ-function, which looks like a piece of a

parabola, and the values of which have to be taken from experiments (see Figure 4, right graphic).

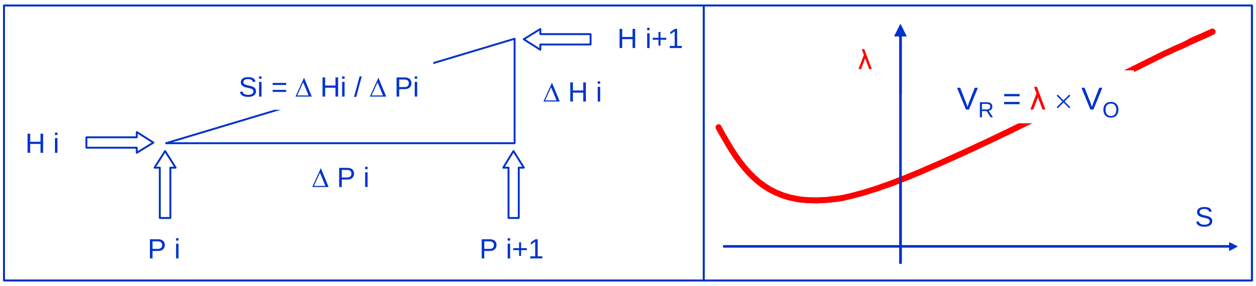

Figure 4: Calculation of the slope S of a course segment using position and altitude data (graphic left) and transformation from original to reference speed depending on the slope (graphic right) (also see explanations in the text)

To this aim the course is recorded and measured by means of GPS and altimetry and then departed into segments of (more or less) constant slope. For each segment the λ-transformation can be done in the way described above. Figure 4 in the left graphic shows how the GPS position data P and the altitude data H are used to calculate the slope S, while the right graphic shows how S and v_0 define $\lambda(S,v_0)$ which then is used to calculate v_R (see Endler, 2006).
After calibrating the λ-transformation to the athlete, the course-specific load profile can be scheduled and optimized.
Finally it has to be taken into consideration that (besides others) age and fitness have impacts on the delay values that in turn characterize the heart rate reaction on speed input. For example, the recovery delay DR will increase by fatigue, which depends on age and fitness as well as on the time already used on the run. As is shown in Figure 5, age, fitness, and the time used characterize a fatigue ΔDR, which modifies the prototypic value DR to the personal situation-specific value DR* = DR + ΔDR.

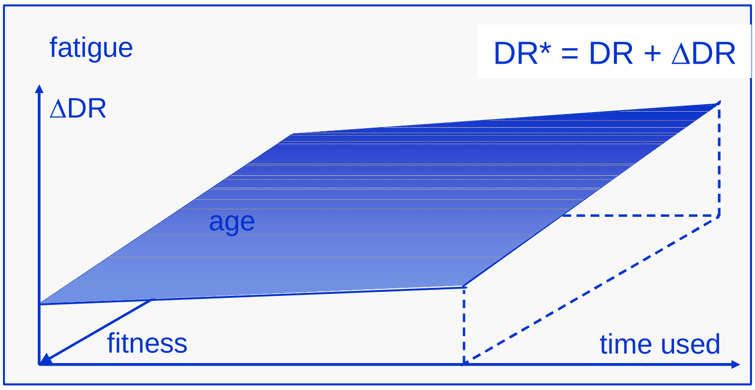

Figure 5: Fatigue depending on age, fitness, and the time used and its impact on the recovery delay DR (also see explanations in the text)

Results

Figure 6 demonstrates the output of a SpeEdi Run analysis: The lower graphic shows the altitude profile with segments and corresponding slope values. The table between the graphics shows the original speed values and the reference speed values of each segment. The

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

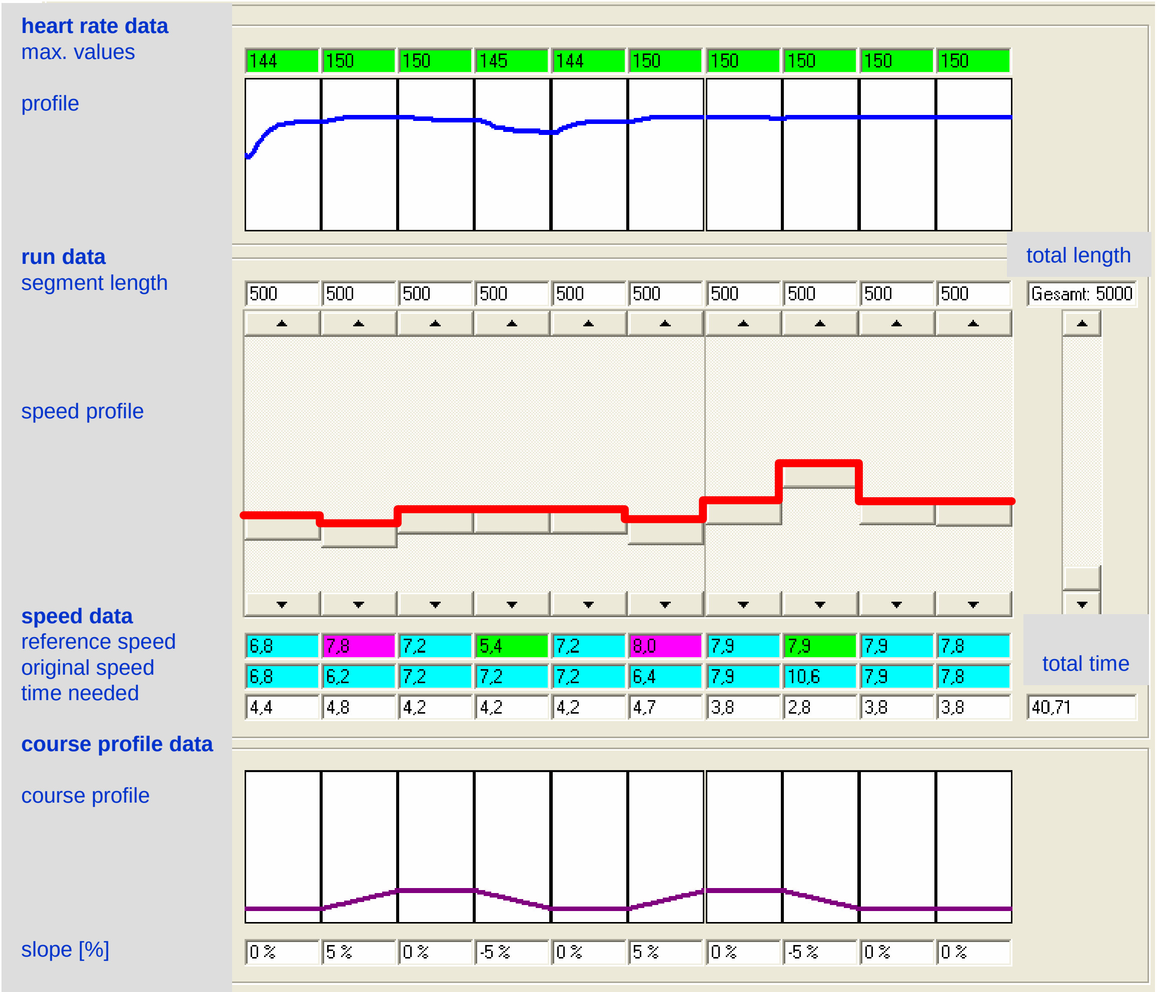

Figure 6: Speed profile optimized under the objection of not to exceed a heart rate of 150 (also see explanations in the text)

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

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See, Walk, and Kick: Humanoid Robots Start to Play Soccer

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Abstract

Robotic soccer superseded chess as a challenge problem and benchmark for artificial intelligence research and poses many challenges for robotics. While simulated, wheeled, and four-legged robots have been playing soccer games for some years now, the RoboCup Humanoid League raised the bar again. This paper describes the mechanical and electrical design of the humanoid robots, which team NimbRo constructed for RoboCup 2006. The paper also covers the software used for perception, behavior control, communication, and simulation. Our robots performed well. The KidSize robots won the Penalty Kick and came in second the overall Best Humanoid ranking.

KEYWORDS: ROBOTIC SOCCER, HUMANOID ROBOTS, WALKING, KICKING, TEAM PLAY

Introduction

What drives thousands of researchers worldwide to devote their creativity and energy to make robots bring a ball into a goal? The answer lies not only in the fascination of the soccer game, but rather in the quest to advance the fields of artificial intelligence research and robotics. AI researchers started to investigate games early-on. Simon predicted in 1958 that computers would be able to win against the human world champion within ten years (Simon & Newell, 1958. Playing chess was viewed as epitome of intelligence. The dominant view at that time was that human intelligence could be simulated by manipulating symbols. While the world champion in chess was defeated by a machine in 1997 (Newborn, 1997), human intelligence is still far from being understood.

The basis for intelligent action is the perception of the world. Already this seemingly easy task frequently exceeds the capabilities of current computer systems. Perceptual processes, which interpret the flood of sensory stimuli to make it accessible for behavior control, are mostly unconscious. Hence, we are not aware of the difficulties involved. The performance of our perceptual system becomes clear only when trying to solve the same task with machines. This applies to behavior control as well. Human locomotion, for example, does not seem to be problematic. That walking and running on two legs is not an easy task becomes clear only when one tries to implement it on a real robot.

Based on these observations, a view on intelligence has established itself over the last two decades that does not rely on manipulating symbols, but emphasizes the interaction of an agent with its environment (Brooks, 1990; Pfeifer & Scheier, 1999). Embodiment and situatedness of an agent in a rich environment enables feedback from the actions of the agent to sensory signals. The complexity is increased significantly when the environment does not only contain passive objects, but other agents as well.

The RoboCup Federation organizes since 1997 international robotic soccer competitions. The vision of RoboCup is to develop by the year 2050 a team of humanoid soccer robots that wins against the FIFA world champion (Kitano & Asada, 2000). Soccer was selected for the competitions, because, as opposed to chess, multiple players of one team must cooperate in a dynamic environment. Sensory signals must be interpreted in real time and must be transformed into appropriate actions. The games do not test isolated components, but two systems compete with each other. The score allows comparing systems that implement a large variety of approaches to perception, behavior control, and robot construction. The presence of opponent teams, which continuously improve their system, makes the problem harder every year. Such a challenge problem focuses the effort of many research groups worldwide and facilitates the exchange of ideas.

RoboCupSoccer Humanoid League

The RoboCupSoccer competitions are held in five leagues. Since the beginning, there is a league for simulated agents, a league for small wheeled robots which are observed by cameras above the field (SmallSize), and a league for larger wheeled robots where external sensors are not permitted (MiddleSize). A league for the Sony Aibo dogs was added in 1999 (Four-legged) and a league for humanoid robots was established in 2002. In the Humanoid League, robots with a human-like body plan compete with each other. The robots must have two legs, two arms, a head, and a trunk. Size restrictions make sure that the center of mass of the robots is not too low, that the feet are not too large, and so on. The robots are grouped in two size classes: KidSize (up to 60cm) and TeenSize (>65cm). The humanoid robots must be able to walk on two legs and must be fully autonomous. They may communicate with each other via WLAN.

Figure 1. Some of the robots that competed in the RoboCup 2006 Humanoid League.

Because the construction and the control of humanoid robots is more complex than that of wheeled robots, initially, there were only less demanding competitions held, but no soccer games played, in the Humanoid League. In 2005, 2 vs. 2 soccer games were started in the KidSize class. The soccer rules follow the FIFA laws, with some simplifications. E.g., the offside rule is not observed and objects are color-coded to simplify perception. Fig.1 shows some of the humanoids that participated at RoboCup 2006.

Humanoid Soccer Robots of Team NimbRo 2006

Fig. 2 shows Paul, one of the NimbRo KidSize 2006 robots and Robotinho, our 2006 TeenSize robot. As can be seen, the robots have human-like proportions. Their mechanical design focused on simplicity, robustness, and weight reduction. The KidSize robots have a height of 60cm and weigh only 2.9kg, including batteries. They have 20 degrees of freedom (DOF): 6 per leg, 3 in each arm, and two in the trunk. Robotinho is 100cm tall and weighs only 5kg. It has 21DOF with an additional roll joint in the trunk. The joints are driven by Dynamixel actuators. In the hip of the KidSize robots and the legs and trunk of Robotinho, we use two actuators per axis. Robotinho has additional spur gears in the hip and in the trunk. The skeleton of the robot is constructed from aluminum extrusions with rectangular tube cross section. We removed all material not necessary for stability. The feet and forearms are made from elastic carbon composite material. Each robot is equipped with a HCS12 microcontroller board, which manages the detailed communication with all Dynamixels. This board also interfaces an attitude sensor, which is located in the trunk. We use a 520MHz Pocket PC as main computer, which is located in the upper part of the robots. This computer runs behavior control, computer vision, and wireless communication. The robots are powered by Li-poly rechargeable batteries.

Figure 2. Paul (KidSize) and Robotinho (TeenSize).

Our robots need information about themselves and the situation on the soccer field to act successfully. The KidSize robots are equipped with two wide-angle cameras. Robotinho has only one camera. The wide field of view of the cameras allows the robots to see their own feet and objects above the horizon at the same time (see Fig. 3). Our computer vision software detects the ball, the goals, the corner poles, and other players based on their color in YUV space. We estimate their coordinates in an egocentric frame, using the inverted projective function of the camera. The relative coordinates suffice for many relative behaviors like positioning behind the ball. To support higher behaviors and team coordination, we estimate the pose of the robot on the soccer field by triangulation over pairs of landmark observations, i.e. detected goals and corner poles. The Pocket PCs are equipped with wireless network adapters. We transmit debug information to an external computer via UDP, where it is logged and visualized. In the opposite direction the game state (kickoff, penalty, etc.) is transmitted to the robots. In order to be able to design behaviors without access to the real hardware, we implemented a physics-based simulation for the robots with the Open Dynamics Engine.

The behavior control for our robots is based on a framework that supports a hierarchy of reactive behaviors. It is structured both as an agent hierarchy (joint — body part — player — team) and as a time hierarchy. The speed of sensors, behaviors, and actuators decreases when moving up in the hierarchy. The lowest level of this framework contains position control for individual joints. It is implemented on the Dynamixel actuators. The joints of a body part are controlled using a kinematic interface that provides, e.g. leg angle, leg length, and foot angle, relative to the trunk. This interface is used to implement basic skills like omnidirectional walking (Behnke, 2006), kicking, and getting-up behaviors (Stückler, Schwenk & Behnke, 2006). Omnidirectional walking allows the robots to combine walking in forward/backward direction with lateral walking and turning on the spot. The robots change the desired walking direction and walking speed based on visual feedback, without the need for stops. The basic skills are used by soccer behaviors like searching for the ball, approaching the ball, avoiding obstacles, and defending the goal. These behaviors activate according to the perceived game situation. Finally, on the team level, the robots communicate via a wireless network to share information about the world state and to negotiate roles like attacker and defender.

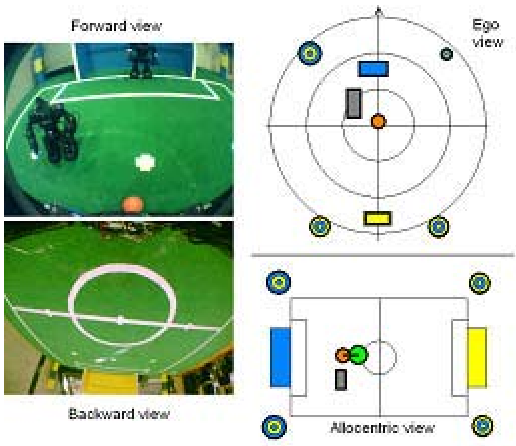

Figure 3: Left: Images of the two cameras of the KidSize robot. Upper right: Egocentric coordinates of key objects detected in the image. Lower right: Localization on the soccer field.

Results and Conclusion

Our robots performed well at RoboCup 2006. In the 2 vs. 2 soccer round robin, the KidSize robots played two games and scored 12:0 goals. They won 6:1 against ROPE (Singapore) in the quarter final and 6:2 against Darmstadt Dribblers & Hajime (Germany, Japan) in the semi-final. In the final, they met Team Osaka (Takayama et al., 2006), as in 2005. Our robots played well in the first half and scored a lead of 4:0. Team Osaka was able to reach a draw of 4:4 after regular playing time. The final score was 9:5 for Team Osaka. Our KidSize robots also kicked penalties very reliably. In the Penalty Kick competition they scored in 31 of 34 attempts and won the final 8:7 against Team Osaka. In the technical challenge, our robot Gerd was one of the two robots able to walk across the rough terrain. Our robots also scored in the passing challenge. Our TeenSize robot Robotinho reached the final of its Penalty Kick competition. In the overall Best Humanoid ranking, our KidSize robots came in second, next only to the titleholder, Team Osaka. Videos of our robots at RoboCup 2006 can be found at http://www.NimbRo.net.

Playing soccer with humanoid robots is a complex task, and the development has only started. So far, there has been significant progress in the Humanoid League, which moved in its few years from remotely controlled robots to soccer games with fully autonomous humanoids. Many research issues, however, must be resolved before the humanoid robots reach the level of play shown in other RoboCupSoccer leagues. For example, the humanoid robots must maintain their balance, even when disturbed (Renner & Behnke, 2006). In the next years, the speed of walking must be increased significantly. At higher speeds, running will become necessary. The visual perception of the soccer world must become more robust against changes in lighting and other interferences.

The 2006 competition showed that most teams were able to kick penalties, but that soccer games are much richer and more interesting. In the team leader meeting after the competition, the majority voted for abandoning penalty kick as a separate competition. Instead, the KidSize teams will focus on soccer games. Unfortunately, most teams do not feel ready to increase the number of players to more than two players per team. This limits the possibilities for team play. As the basic skills of the humanoid soccer robots improve every year, teams will be able to leverage the experience from the other RoboCup leagues when focusing on the more complex soccer behaviors and on team play.

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Biomechanical Modelling of a Golf Swing by Means of the Multibody-Kinetics Software "ADAMS"

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Abstract

Previous double pendulum models of the golf swing could have included some over-simplifications (only two model segments, 2D analysis of 3D motion, rotation around a fixed pivot point). This has been overcome by full-body models driven by motion capture data from real swings. However, information regarding the validity of these models is still limited. Therefore, the aim of this study was to create and to validate a full-body model of the golf swing. A Vicon motion analysis system (12 cameras, f=250 Hz) was used to record one subject performing a golf swing with a driver club. By applying the software ADAMS with its plug-in LifeMOD, a full-body simulation of the swing was created based on the recorded motion. Ground reaction forces and the trajectory of the club head were not used as model inputs, but served as independent validation parameters instead. Comparison of the experimental data with the model outputs showed general agreement and a promising potential of the model. In conclusion, it was shown that the software ADAMS with its LifeMOD plug-in is an efficient tool to create biomechanical models of golf swings. Future models should include the shaft deformation and an impact function.

KEYWORDS: BIOMECHANICAL MODELING, GOLF SWING, VALIDATION

Introduction

In 1968, Cochran and Stobbs suggested to model the golf swing by means of a two-dimensional double pendulum. Several previous studies used this approach to investigate the effect of a delayed wrist release (e.g. Jorgensen, 1970) and the coordination of torso, arm and club movement (e. g. Sprigings & Mackenzie, 2002). Two assumptions of these models were (1) that the arms and the club rotated about a fixed pivot axis and (2) that all segments moved within one static plane. However, it has been found that these assumptions might not be true (Coleman & Rankin, 2005). Furthermore, Letzelter and Letzelter (2002) pointed out that two-dimensional models do not allow analyzing how torso and lower body contribute to the swing. Due to the disadvantages of the two-dimensional double pendulum model, researchers created more complex full-body models of the golf swing. For example, McGuan (1996, 2001) presented a full-body model of the golf swing based on 3D motion capture data. He performed his simulation in two steps: During the first step, body segments were moved according to marker trajectories registered during a real swing, and the angular displacement of each joint was recorded. During the second step, the motion capture data was removed and the model was set into motion by joint torques. Through the use of an optimization routine, each joint produced the amount of torque necessary to resemble the previously recorded joint angles, resulting in a forward-dynamics simulation of the motion. McGuan gave no information as to how he validated the model.

As has been shown above, previous two-dimensional models of the golf swing might be too simplistic, and no information regarding the validity of previous full-body models is available. Therefore, the aim of this study is to determine the suitability of McGuan's (1996, 2001) approach to model the golf swing. In order to do so, a similar model will be created and validated by comparing model outputs with data measured independently during the real swing. The golf club will be modeled as a rigid body and the model will not include the ball contact.

Methods

The subject was one highly skilled golfer (Handicap 10, 22 years, 1.85 m, 79.4 kg). Spherical, reflective markers were attached to 31 anatomical landmarks and recorded throughout the swing using a Vicon 8i motion capture system (12 cameras, f = 250 Hz). The marker set used was based on recommendations from BRG (2005), which were adjusted according to the results of own test trials (Betzler et al., 2006). Additional markers were placed on the back, hip and head of the golfer. One marker was placed on the shaft of the golf club below the grip, another one just above the club head. Ground reaction forces were recorded using two force plates (Model 9826AA, Kistler).

(a) (b) (c)

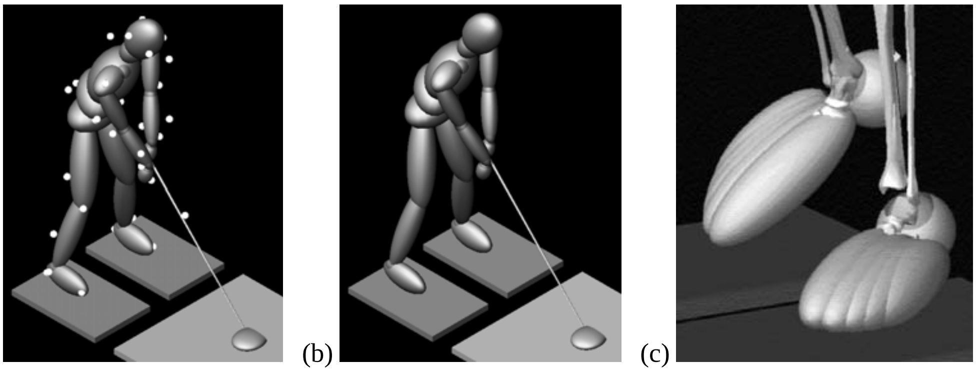

Figure 1: The full-body model addressing the ball: (a) modeling stage (motion capture markers are activated and control the motion) and (b) in the simulation stage (motion capture markers are disabled and joint torques drive the model). (c) Ellipsoids defining the ground contact areas of the feet

The full-body model was created using the software ADAMS (MSC, Inc.) with its LifeMOD plug-in (BRG, Inc.). A general description of the modeling procedure used can be found in Hofmann et al. (2006) and in the introduction of this paper. In order to define the boundary conditions of the model, previous authors suggested attaching the feet rigidly to the ground, thereby allowing for only minor foot movements (BRG, 2006; Nesbit et al., 1994). The present study took a different approach by using contact areas rather than fixed joints in order to allow free foot motion (see Figure 1 (c)).

Shaft and head of the golf club were modeled as rigid bodies in this study because the deformations of the club head are on a very small scale, and, according to previous studies, the effect of shaft deformation on the dynamics of the swing is small (Milne & Davis, 1992). A cylinder with variable wall thickness according to dimensions given by Cheong et al. (2006) represented the shaft. The club head was designed as a hollow ellipsoid, which was cut off in the area of the club face. A plate represented the club face. The club head did not include any further details. The club and both hands were connected using a very stiff bushing joint (BRG, 2005).

Results and Discussion

A full-body model driven by joint torques and allowing to simulate a golf swing (see Fig. 1 (b)) has been created. It is the basic aim of this study to validate this model to provide the validation needed before it can be used for biomechanical analyses of the swing. Since it is not possible to validate the joint torques created by the model directly, the kinetic validation of the model has to be achieved indirectly.

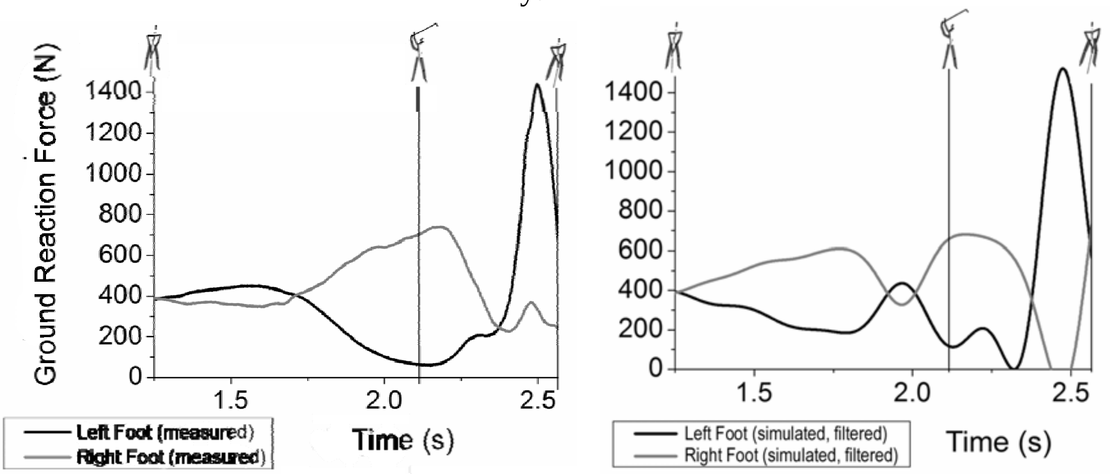

Figure 2: Comparison of ground reaction forces as measured experimentally (left) and as determined during simulation (right).

When looking at the raw data of the ground reaction forces produced by the model, it became apparent that high-frequency noise and force peaks overlaid the signal. These perturbations were reduced by applying a low-pass Butterworth filter. After filtering the data, it then became possible to compare measured and simulated ground reaction forces (see Fig. 2). Both the model and the golfer shift their weight to the right foot during backswing and shift it dynamically back towards the left foot during downswing. While this general pattern is identical for the real player and the model, some differences do become apparent when looking at Figure 2. The model does not reproduce the small weight shift that initiates the backswing of the real player. Furthermore, the model seems to loose balance for a brief moment at the transition from backswing to downswing. The differences in ground reaction forces could be explained by the model's construction from rigid bodies with simplified joints and by the fact that the foot contact did not resemble the shoes of the golfer accurately. Furthermore, the rigid club might have caused force peaks during the transition from backswing to downswing, resulting in the model shifting its weight to the left foot for a short period of time.

The ability to bring the club in an accurate impact position reflects the quality of the full-body motion of the golfer. This applies to a model of the swing just as much as to a real player. To validate the model, the trajectory of an additional motion capture marker at the tip end of the shaft was compared to the displacement of a virtual marker placed in the same position. First of all, it had to be noted that there was a time offset of 13.6 ms between model and real swing. This offset might have been caused by the rigid modeling of the shaft, which prevented the characteristic forward bending of the shaft that usually occurs just before impact (Milne & Davis, 1992). The deviation of the model's impact position was 14 mm. The club head velocity at impact was 0.25 m/s higher (0.5%) for the model than recorded during the real swing. Considering the complexity of the model, the accuracy of the model's club head trajectory is satisfactory.

Conclusion

In summary, the model presented in this paper provides a good base for further studies on the full-body kinetics of the golf swing. However, modeling the shaft of the golf club as a rigid body seemed to have caused deviations between model and reality. The modeled shaft could not bend forward at impact, which apparently resulted in a temporal offset. Furthermore, future models will have to include an impact function, as neglecting the impact resulted in the club moving too fast during follow-through, causing the model to lose balance. Therefore, a deformable shaft model and an impact function are going to be added to the model introduced here. With the implementation of these improvements, it promises to be a valuable basis for further studies of the full-body kinetics of golf swings.

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Performance Prediction in Cycling Using Antagonistic Models

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Abstract

Two antagonistic models are used to model the training-performance relationship during an eight week cycling training, with a prediction of the performances in the last week of training. Results indicated different qualities of the model fits for the test data for both models. Mean differences between predicted and real performances were 2.39% for the Fitness-Fatigue-Model and 4.43% for the PerPot-Model. However, the Fitness-Fatigue-Model parameters remain questionable in terms of physiological interpretation. Hence, the PerPot-Model is preferred, although the general applicability for performance prediction in the presented cycling training situation can not be supported.

KEYWORDS: MODELLING, TRAINING, CYCLING

Introduction

In training science a main focus is set on the analysis of the athletes' training process. The adaptation process as well as the performance response to physical training are known to be highly individual (Mester and Perl, 2000). In the recent past, computer aided simulative models have been utilized to analyze the interaction of load and performance in training. Systems with an "antagonistic structure" have been established in modeling individual performance characteristics during the training process. The basic assumption of such models is, that the training load (as the input component) has both positive and negative effects on the performance (as the output component) of the "dynamical system" athlete.

Within the framework of the Fitness-Fatigue-Model, proposed by Banister (1982), two factors generated by daily training (w), called fitness (p) and fatigue (f), affect performance (a). Each of them is mathematically described by a first order differential equation. The difference between the two components represents how well the athlete performs at any time. The quantity of impulses generated from training is defined by weighting factors (k1 and k2) and the decline of both components between two training sessions is described by an exponential decay with relative time constants (t1 and t2). With respect to the initial values (a0 – initial performance), individual model parameters are now estimated by fitting the modeled performances to real performance data until a least squares best fit, using Equation 1 (equation modified after Banister, 1982). Then the model parameters enable an interpretation of the individual adaptation behavior of the athlete, concerning a more fatigue or a more fitness induced performance response to training.

$$a(t) = a0 + k1 \bullet [\, p(t-i)e^{-i/t1} + w(t)] - k2 \bullet [\, f(t-i)e^{-i/t2} + w(t)] \qquad (1)$$

The basic PerPot-Model implies flows between potentials. Two buffer potentials for strain (SP) and response (RP) are fed by the load rate as the input component of the model (represented by the time series of training load). These potentials influence the performance potential (PP - as the output component of the model) in an antagonistic way: The response potential raises the performance potential and the strain potential reduces it (Perl, 2001). The dynamical (and non-linear) behavior of the model is achieved through specific delays of strain flow (DS) and response flow (DR), where flow rates additionally depend on the current states of the potentials. During calibration the model parameters are determined on the basis of real training and performance data.

The behavior of the calibrated models is regarded to represent the athletes' individual performance response to training. One application for such models would then be the prediction of future performances from known training history.

The aim of the study was a retrospective analysis of the training-performance relationship in cycling with two antagonistic models during an eight week cycling training and the prediction of the performances in the last week of training.

Methods

Training

Training and performance data of ten athletes (sport students; 9 male, 1 female) were obtained during an eight week cycling training. The training program consisted of periods with varying volumes and intensities. During training sessions with the personal bicycles on the road, heart rate was continuously recorded. Training load was quantified using the TRIMP-score proposed by Banister (1982), where the training impulse is calculated from the duration multiplied by the delta heart rate exercise ratio of the training session (equation: cp. Banister, 1982), in order to account for both the training volume and the intensity. The mean mechanical power output was measured during a 30-seconds all-out cycling exercise as an indicator of the performance three times a week. All performance values were transformed by dividing the power outputs of the 30-s tests by the maximal value, intraindividually, reached during the training period (according to 100 units).

Modeling

Model parameters were individually calculated using the test data (weeks 1-7, n=13-19). PerPot modeling was done using PerPotV10-4 simulation environment (Perl). For the Fitness-Fatigue-Model parameters were calculated in limited ranges (cp. Busso et al., 1997) with the data analysis package Origin 7.0 (Originlab®), using an implemented least squares fitting algorithm. Coefficient of determination (r^2) between modeled and real performance data was calculated as an indicator for the goodness of the model fit. On the basis of the model parameters and the given training loads the last two performances (week 8) were then predicted. The mean relative difference between predicted and real performances was calculated as an indicator for the quality of the prediction.

Results

The model fits for the test data offer different qualities. The coefficients of determination lie in a range between $r^2=0.000$ (M2) and $r^2=0.833$ (M7) for the Fitness-Fatigue-Model and $r^2=0.134$ (M4) and $r^2=0.928$ (M7) for the PerPot-Model (see Table 1). The time course of the training period is exemplarily shown for one athlete (M7; see Figure 1).

The differences of the two predicted performances result in a mean value of 2.39% (range 0.83 – 5.17%) for the Fitness-Fatigue-Model and 4.43% (range 1.66 – 8.29%) for the PerPot-Model (see Table 1). Although smaller differences can be observed for the Fitness-Fatigue-Model, at least one of the model time decays (t1 and t2) is marginal to the limited range of values (t1 between 30 and 60 days, t2 between 1 and 20 days) in nine out of ten athletes.

These ranges have shown to be empirically and physiologically reasonable in previous studies (cp. Busso et al., 1991; 1997).

Table 1. Model parameters for the test data (n: performance measures, t1 and t2: time constants of fitness and fatigue, k1 and k2: weighting factors of fitness and fatigue, DS and DR: delays of strain and response, r²: coeff. of determination) for all athletes (male: M1-M9, female: W1). The relative difference (Diff.) is calculated as the mean difference between the last two predicted performances and real performances (week 8). Mean difference (Mn) for all athletes is calculated.

	Fitness-Fatigue-Model								PerPot-Model				
	n	t1	t2	k1	k2	k1/k2	r²	Diff.%	DS	DR	DS/DR	r²	Diff.%
M1	17	36	1	0.017	0.022	0.781	0.816**	0.83	3.6	2.4	1.5	0.668**	3.90
M2	14	32	20	0.000	0.002	0.000	0.000	1.60	1.5	1.5	1.0	0.359*	1.66
M3	14	60	20	0.012	0.011	1.082	0.628**	1.06	3.4	2.1	1.6	0.753**	8.29
M4	13	54	4	0.001	0.004	0.358	0.413*	1.46	1.8	1.3	1.4	0.134	4.49
M5	16	60	20	0.011	0.011	1.039	0.579**	2.61	2.5	2.0	1.3	0.736**	2.62
M6	19	60	20	0.024	0.027	0.904	0.468**	1.73	2.9	2.5	1.2	0.283*	2.42
M7	18	30	12	0.017	0.016	1.085	0.833**	5.17	3.9	1.9	2.1	0.928**	5.28
M8	16	30	1	0.008	0.000	>>1	0.597**	3.18	3.4	2.5	1.4	0.810**	3.22
M9	17	30	5	0.009	0.009	1.026	0.402**	1.57	2.9	2.5	1.2	0.337*	6.24
W1	17	30	1	0.007	0.003	2.430	0.569**	4.72	3.0	2.5	1.2	0.612**	6.18
Mn								**2.39**					**4.43**

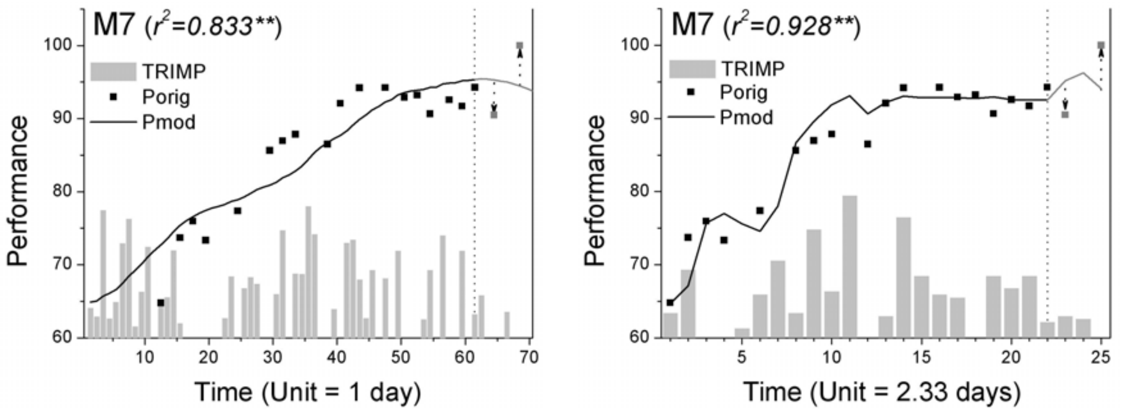

Figure 1. Model fits of athlete M7 with the Fitness-Fatigue-Model (left) and the PerPot-Model (right) for modeled (Pmod) and real performances (Porig). The time course of the last two predicted performances is colored gray.

Discussion

For the model fits good as well as poor results could be obtained for both models. Reasons for poor model fits could be a lack of performance dynamics throughout the training period, probably caused by insufficient training load (as observed for athlete M2). The short term performance dynamics can not be assessed, not even for the good model fits (as for example athlete M7, see Figure 1). However, these short term changes could in part result from a certain variability of the performance, in this case the mean mechanical power output over 30 s on the cycling ergometer. For the Fitness-Fatigue-Model it is considered critical that, in nine out of ten cases, at least one of the time constants is equal to the upper or lower limit of the value range (cp. Busso et al., 1991; 1997). This precludes the interpretation of the model behavior in terms of fast recovering abilities (t2 low) or a stable fitness level (t1 high) of the

athlete. Even the ratio of the weighting factors (k1/k2) can not clear up the dominance of one component in this case. Similar results for the time constants could be obtained in the studies of Busso et al. (1991; 1997) with runners and cyclists.
In the PerPot-Model the ratio of DS/DR gives, with respect to the time scale, an idea on how fast strain is responding compared to recovering abilities of the athlete. A ratio >1 indicates that strain is responding later and thus represents a well trained state of the athlete. This is qualitatively characterized by a transient behavior of the performance (see Figure 1) and could be observed for all athletes, except M2 (see Table 1).
The prediction of the performances during the last training week gives different results. The lower mean difference for the Fitness-Fatigue-Model will not be preferred due to the lack of interpretation of the model parameters. With the PerPot-Model high differences could be observed for some athletes, which can not support the general applicability of the model for predicting future performances in the presented cycling training situation. Possible reasons may be unstable performance levels of the athletes, a too short training period or the variability in the measured performance.

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„sail:lab" - Development and Use of an E-Learning Application in Mathematics and Sport Sciences

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Abstract

sail:lab, as an interdisciplinary project of mathematicians and sport scientists, uses the physical description of sailing to develop an E-Learning component, which can be integrated in Blended Learning scenarios in both departments. By calculating the forces and moments due to wind and current which take effect at sail, hull, rudder, and fin, the movement of a jolly-boat is visualized. An instantaneous execution of computation and a graphical user interface, which accomplishes the association of sailing instruments, enable an intuitive use, especially for sailing experienced users. So, sail:lab originates an amended theory - practise transfer, that is material to reflection and consideration for sport students. In the opposite this simulation process is an exemplary instance for practise – theory transfer in mathematics.

KEYWORDS: SIMULATION, SAILING, DIFFERENTIAL EQUATIONS, CONTEXT-SENSITIVE USE

Introduction

The hereby presented project "sail:lab" is effected interdisciplinary by the department of mathematics and the department of sport sciences of the University of Hamburg. In the first place the subject of this joint venture is to develop a physical-mathematical model for the simulation of a moving sailing boat. The pursued result of a stand-alone application should then enrich the teachings of both departments. On the one hand in mathematics it can be used as an ideal type possibility of modelling with differential equations (the underlying models are based on differential equations). On the other hand in the context of sport studies, such a quantitative simulation provides an improved transfer from theory to practical experience regarding the education of sailing.

Modelling

We postulate the physical dimension of the boat to be given. After definition of different input data - like a two dimensional wind field, a two dimensional current field, the position of sail and aviation and the position of the sailor on the boat (modifiable during calculation process) – the user receives the output data relevant for the sailor: The position of the sailing-boat, the components of the velocity, the angle of direction and the angle of velocity, the heel and the rate of change of the heel angle. The corresponding balance equations of dynamical forces yield a system of differential equations, calculated in a real-time operation.
The main part of the mathematical model consists in the calculation of the forces F, which drives the boat into motion, and the numerical solution of the kinetic equation of motion. All

values will be considered in two coordinate systems, one fixed system (x,y,z) and another one (ξ,η,ς) moving with the boat.
Decisive for the movement of the boat are the forces due to wind (sail-force) and due to current (hull-force).
Atmospheric wind and fair wind are accumulated up to the apparent wind. The sail force can be divided into two components, the buoyant force A_{sail} vertical and the resistance force W_{sail} parallel to the direction of apparent wind. Buoyant and resistance coefficient C_A respectively C_W, depend on the angle between wind direction and sail and can be taken from tables, which are part of the program. So buoyant force and resistance force can be calculated due to $A_{saill} = \frac{1}{2} C_A \cdot s \cdot v_{air}^2 \frac{p}{RT}$ and $W_{sail} = \frac{1}{2} C_W \cdot s \cdot v_{air}^2 \frac{p}{RT}$, where s is the surface area of the sail and v_{air} is the velocity of the apparent wind. The density of wind current is air pressure p divided by air temperature T and universal gas constant R.
The torsional moment is related to the ζ-axis (the attitude axis) due to the sail and therefore is given by the cross product of the sail force and the position vector of sail pressure point.
The subaqueous hull force is generated by the current. Analogue to the wind the apparent current v_{ocean} is the summation of ocean current and fair current. The force normal to the hull is dynamical pressure multiplied by area of hull surface. Thereby the dynamical pressure p is given due to $p = \frac{1}{2} \rho \cdot v_{ocean}{}^2$, with the density of water named ρ.
The hull by itself can be approximated by the use of a cylinder with a polygonal base area and constant height. For each part the force can be calculated as $F_i = p \cdot A_i = \frac{1}{2} \rho \cdot A_i \cdot v_n^2$.
The hull force is the sum of these forces and takes effect at the lateral pressure point, which is assumed to be in the middle of the fin. Equally the torsional hull moment (concerning the ζ-axis) results from the summation of torsional hull moments at the different polygon boat sides.
Further forces yield the impact due to the apparent current along fin and rudder. Both are conceived as flat planes in the water. The incident flow induces buoyant and resistance force, where the vertical component of force can be neglected. As pressure point we choose the plane center so the resulting moment (regarding the ζ-axis) at the barycentre of the boat can be calculated concerning the position of these midpoints.
The heel of the jolly-boat originates in the moment of sail and fin in respect of the axis of gyration, which is assumed to be the longitudinal ξ-axis. So the barycentre is part of the axis of rotation. The uplifting moment of the boat and the sailor act in opposition to the sail- and fin moment. If I is defined as the moment of inertia accumulating boat and sailor and α is the angle of heel we get the equation $I\ddot{\alpha} = M_{sail} + M_{helmsman} + M_{fin} + M_{up}$, where M_i is the respective moment concerning the ξ-axis and the uplifting moment M_{up} depends on the angle of heel and can be taken from a boat specific table.
The equation of motion therefore appears as a system of eight differential equations, which should be computed numerically.

The following terms were used:

- x and y are absolute coordinates referring to the fixed system
- u and v are velocities in x, y direction
- φ is the horizontal angle of the boat
- v_φ is the velocity of rotation
- α and v_α are the vertical rotation angle respectively the longitudinal axis of the boat and the time rate of change
- M_ζ and M_ξ are the resulting moments of the boat concerning to the ζ-axis (horizontal rotation) and ξ-axis (vertical rotation).

$$\dot{x} = u$$
$$\dot{y} = v$$
$$\dot{u} = \frac{1}{m} F_x$$
$$\dot{v} = \frac{1}{m} F_y$$
$$\dot{\varphi} = v_\varphi$$
$$\dot{v}_\varphi = \frac{M_\varsigma}{I}$$
$$\dot{\alpha} = v_\alpha$$
$$\dot{v}_\alpha = \frac{M_\xi}{I}$$

The solution is determined with the help of the procedure of Runge and Kutta as it is applied by Dormand and Prince with the order of p=5, q=4 (cp. Dormand / Prince, 1980; Papacostas / Papageorgiou, 1996), known in MATLAB as ode45. For a better performance we use a minimal increment.
At the end all relevant parameters are placed to the users' disposal: position, course, velocity, heel, position of fin and sail, magnitude and angle of apparent wind and apparent current, position of the sailor.

Realisation

The model was implemented in the Macromedia Tool Director MX 2004. The graphical design is similar to the Flash-based sailing-software „e-törn“ (Hebbel-Seeger, 2003) (see fig. 1). However, the underlying concept is fundamentally different. „e-törn“ reduces the system boat – sailor to a few basic relations whereas sail:lab is intended to map the reality by a physical model. Especially the last point presents a challenge on the screen-design. Both an intuitive handling and an easy approach to the physical parameters are required.

Use

The distinctiveness of the application is the integration into the education of different departments of the university. In mathematics, the simulation has an example character in the field of differential equations. This suggests a deployment in lectures for modelling of the department of mathematics. In sport studies sail:lab supports the reflection and analyses of the practical moving-experience.
Hence we see sail:lab as a learning object, which can be interpreted context-sensitive: In sport studies sail:lab serves the purpose of reflection and inspection of the transfer from theory to practical experience in sailing from a learners point of view. In the learning context of mathematics, sail:lab presents an ideal type example of mathematical modelling of technical process, simulation and analysis. Furthermore a simulation like sail:lab exemplifies the mathematical matters and motivates an indepth contention, which is especially an important benefit for teaching export in natural and engineering sciences.

Beyond the perspective of access, the context sensitivity refers to the teaching-learning-situation, as well: sail:lab could be used in a blended-learning-scenario, which enables the learners to find solutions to problem domains, that were raised in lessons. This can be achieved by manipulating and working on the learning object (cf. Hebbel-Seeger, 2005). Likewise sail:lab offers the deployment in lessons, by enabling a teacher to visualise sailing theory, as well as an example for the use of differential equations.

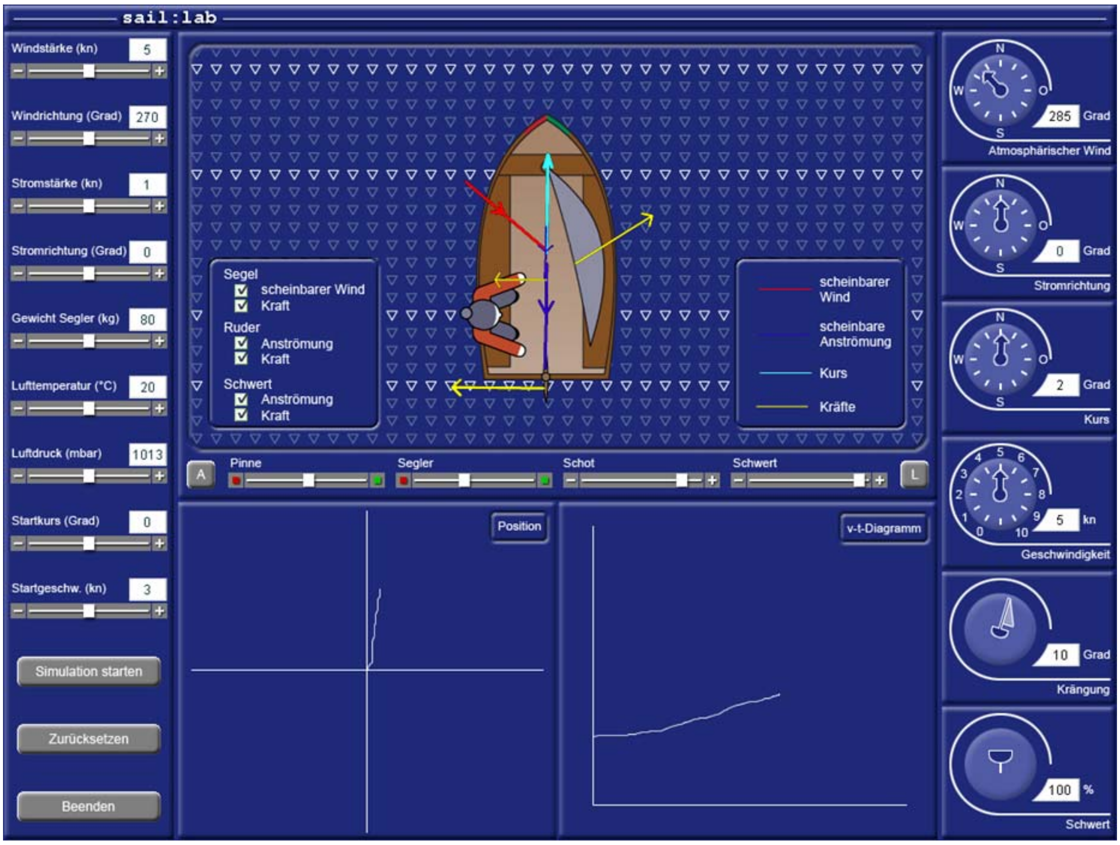

Figure 1: The “sail:lab”-Interface.

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Recognizing of Movement Samples on the Basis of the Kinetics by Fuzzy Logic by the Example of Different Giant Swings

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KEYWORDS: PATTERN RECOGNITION, KINETICS, FUZZY LOGIC

Introduction

No movement resembles the other one, however we can recognize patterns of movement for example a giant swing as such. The aim of the experiment was to examined whether a differentiation of two movement classes of giant swings on the basis of kinematic data is possible by fuzzy logic (Zadeh, 1984).

Methods

33 giant swings (n1 = 21 preparing giant swings before Kovacs, n2 = 12 Tong-Fei giant swings before Tsukahara dismonts) were examined. The videos of the world championships 1997, 1999 and 2001 as well as of international DTB-Cup 2003 were provided by the IAT Leipzig. The coordinates of relevant hinge points needed for the pattern recognition were determined with the software mess2D (two-dimensional videometric software by Volker Drenk, IAT Leipzig). The coordinates of the wrist, the shoulder, the hip and the knee joint were seized, so that the main correcting variables of the giant swing, arm- and leg-body-angles (ABA and LBA) could be calculated. These were modelled in purchase for the overshot segment of a circle of the arms by a cubic spline interpolation to differentiable trigonometric functions (see fig. 1 on next page). The trigonometric functions, as a mathematical description of the movement, makes the determination of the different movement behavior of athletes mathematically possible.

1. In which position a defined angle is reached (ABA = 165°, LBA = 0°).
2. In which position of motion of a body angle reverses the direction and how large the maximum/minimum angle is.
3. In which position the angular rate takes place, how large is the angle in this position and how large is the change of angle.

First, six characteristics, by which the curve shapes can be differentiated, were defined. With the comparison of the curve shape the following characteristics appear as particularly characteristic of the respective movement class.

- For the ABA:

1. the position (overshot segment of a circle of the arms) when closing the ABA on 165° after the max. (over) stretching
2. (A) the position of the maximum angular rate in the ABA after maximum overstretching with (B) the appropriate angle and (C) with the change of angle in this position.

- For the LBA:

3. the position when closing the LBA on 0° after max. overstretching
4. (A) the position of the largest overstretching of the hip with (B) the appropriate body angle
5. (A) the position of the largest change of angle in the hip between the maximum flexion and overstretching with (B) the appropriate body angle and (C) witch the change of angle in this position
6. (A) the position of the largest angle change in the hip after maximum overstretching with (B) the appropriate body angle and (C) the angle change in this position.

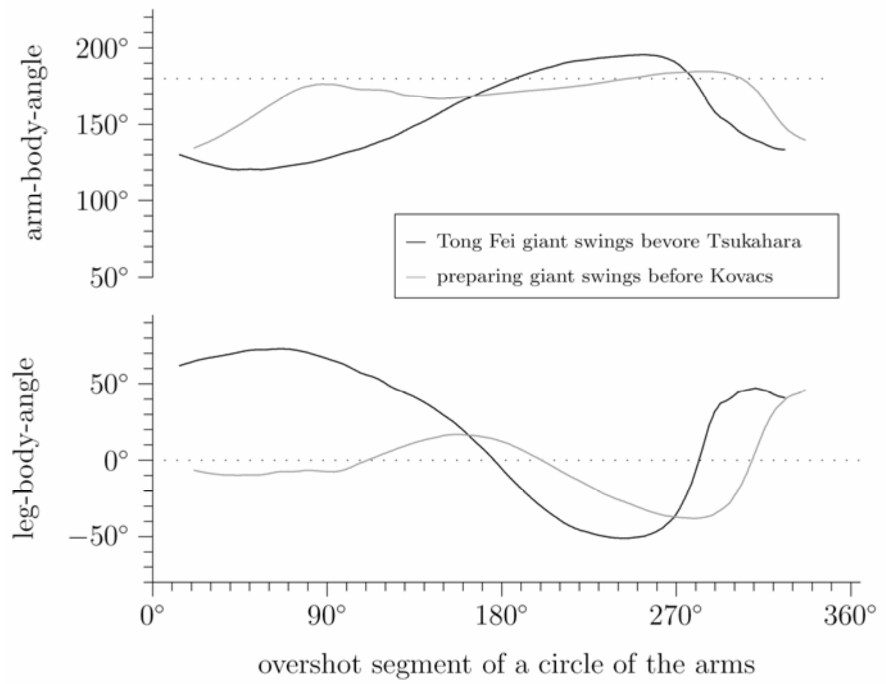

Figure 1. middle of the arm- and leg-body-angles.

The characteristics of the analyzed movement pattern were seized automatically for the six characteristics mentioned above by the computer and put down in a data base. The median (Mdn) as well as the minimum (min) and the maximum (max) were determined. Two additional values were calculated, which are smaller than the minimum respectively higher than the maximum. Thus characteristics which are close to the well-known range of variation were recognizable. For this extension of the range of variation half of the difference between the median and the minimum was subtracted from the minimum and determinated as the smallest outside border (leo: left out). As well as half of the difference between maximum and the median were added to the maximum and determinates the largest outside border (rio: right out). As a consequence the affiliation classification of the presence of a characteristic can be carried out. For comparing characteristic developments with the references of the prototypes fuzzy sets (see fig. 2 on next page) were defined. They shall describe the affiliation of a characteristics agreement linguistically with the respective prototypes.

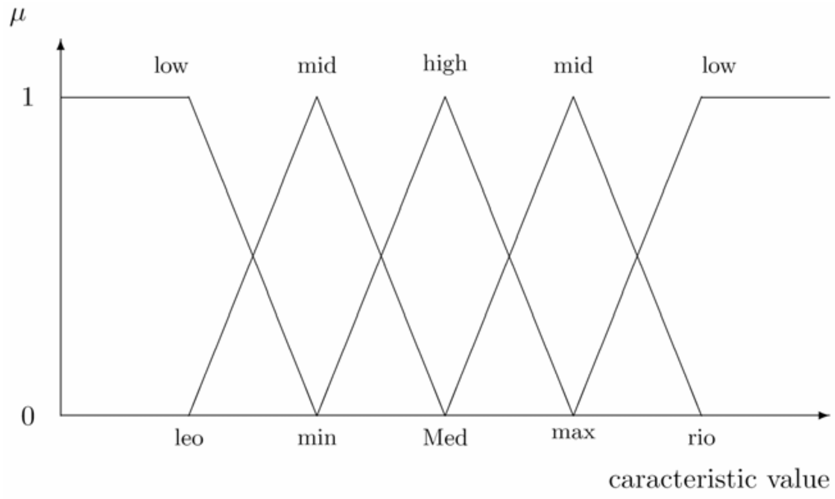

Figure 2. fuzzy sets

The agreements are divided into the fuzzy sets “high”, “mid” and “low”. Thereby it was assumed, that during a characteristic of the recognizable moving pattern, a “high” agreement is given. With the fuzzy rules which can be set up (see fig. 3), and which shall meet a statement about the characteristic agreements, it was differentiated between characteristics with one, two or three characteristic developments (see above).

rule	if	then
01	high	secured
02	mid	high
03	low	very low

rule	if	and	then
04	high	high	secured
05	high	mid	very high
06	high	low	low
07	mid	mid	high
08	mid	low	low
09	low	low	very low

rule	if	and	and	then
10	high	high	high	secured
11	high	high	mid	very high
12	high	high	low	high
13	high	mid	mid	high
14	high	mid	low	low
15	high	low	low	very low
16	mid	mid	mid	high
17	mid	mid	low	low
18	mid	low	low	very low
19	low	low	low	very low

Figure 3. fuzzy rules

The defuzzification took place according to the center of gravity method and was described by the means of the linguistic values “excluded”, “very low”, “low”, “high”, “very high” and “secured”. Certainly (s) of an agreement for each characteristic (n) and for all applicable movement samples (B) was determined and the probability of the sample agreement of the movement sample which can be recognized with the prototypes was determined. The probability (p) for the agreement of the prototypes and the sample to be recognized was calculated as follows:

$$p(B) = \sum_{i=1}^{n} m_{iB} s_{iB}$$

In the accomplished experiment for each movement sample the probability of a sample agreement with the applicable movement classes, was accomplished.

Results

Altogether the trigonometric functions of the examined movement samples were characterized by nearly parallel curves within a movement class. All recognizable movement samples could be assigned to the correct class. The middle probability of allocations of the sample agreement was with p = 80, which corresponds to the linguistic value "very high".

Discussion

Apart from the pattern recognition by artificial neural nets the procedure of the sample agreement of individual characteristics described here represents a further possibility for the classification of movement samples with the help of a Fuzzy logic. These movement samples which were classified here belong to "the pattern family" of the giant swings. They can be differentiated by some few characteristics, however they exhibit also common characteristics, by which they can be assigned to a superordinate class (giant swings). In case of a larger spectrum of allocation possibilities in such a hierarchy the comparison offers itself individual movement characteristics, since it can be built up more flexible than a view on the entire sample.

Thus the results of the experiment open possibilities for future potential application fields. Probably it is possible to differentiate not only different movement techniques but regognize "noticeable problems" and "errors" of a movement pattern automatically similary as it was shown by Eimert (1997) with the example of shotput by means of neural nets.

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Modelling with BRG.LifeMOD™ in Sport Science

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Abstract

Besides the actual state of the condition, the performance of an athlete is highly influenced by the way of executing the movement. So this factor is said to be more and more important. In order to find out and use these potentials, sport science profits from the power of computers for example with modelling and simulating special movements. This article describes the basic functions of a modelling software (BRG.LifeMOD™) using the field of inverse dynamics. Additionally, the results of a first application will be presented, showing a comparison between the forces while walking over a forceplate and the calculated forces with BRG.LifeMOD™ based on inverse dynamic. The data gives evidence that the use of the modelling software can be quite useful in future.

KEYWORDS: MODELLING, PLUG-IN-GAIT, LIFEMOD

Introduction

In sport science, biomechanic models are used for simulating, analysing and finally improving movements. Especially with the help of computergenerated models it is possible to reproduce extensive biomechanic-systems, even to simplify them by using rigid-body-systems (Bächle, 2004, S. 18-19). Another possibility to create a biomechanic model is given by the inverse dynamic. Therefore the analysed data of a real human movement has to be transferred on a model representing a human being as well. The following simulation of the movement enables the calculation forces e.g. groundreaction forces or moments of force in different joints. For example see the model of a figure-skater (Knoll & Härtel, 2005, S. 134-137). The software MSC.Adams™ offers in combination with the plug-in BRG.LifeMOD™ the possibility of modelling real human movements based on the principle of the inverse dynamic.

So the aim of this study is to present the use of the plug-in BRG.LifeMOD™ and the results of a first application regarding the groundreactions forces of a walking human being.

Methods

In order to develop a model with the software it is necessary to make important settings concerning anthropometric data (age, size etc.). Then the separate parts of the model have to be fit together via joints, while different options (amplitude of movement, stiffness and dampings) can be made. To transfair the data of the kinematic movement to the model, the positions of defined points of the body have to be selceted. The markers of the Plug-in-Gait Marker Set give a recommendation of placing the markers (Fig. 1).

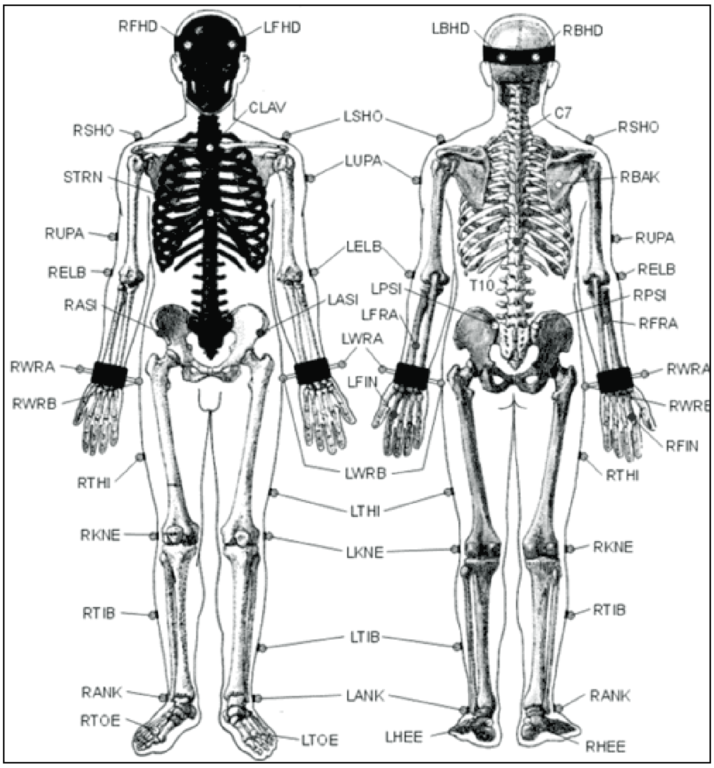

Figure 1. Positions of the Plug-in-Gait Marker Set (BRG.LifeMOD™, 2005, S.390)

Before starting the calculation of the forces, the joints of the model have to be declared as passive, so that the markers learn the movement by the the data of the original motion (inverse dynamic). Finally, the simulation of the movement can be run, whereas the markers have to inactive now.

For having a first basis concerning the function and accuracy of BRG.LifeMOD™, the research of human gait was done. Therefore two Kistler-forceplates (type 9826AA, f=1080 Hz) were used to define the groundreaction forces directly. Simultaneously, the movement was recorded using an infrared system (VICON 8i-system, consisting of twelve cameras, f=120 Hz, Oxford Metrics) to get the input-data for modelling and determining the groundreaction forces with the help of the invers dynamic. The subject (height 1,78 m and weight 70 kg) was marked with 39 markers based on the Plug-in- Gait Marker Set.

Results and Discussion

The following figures show the developping of the groundreactions forces measured by the Kister-forceplate (Fig. 2) as well as calculated via BRG.LifeMOD™ (Fig. 3).

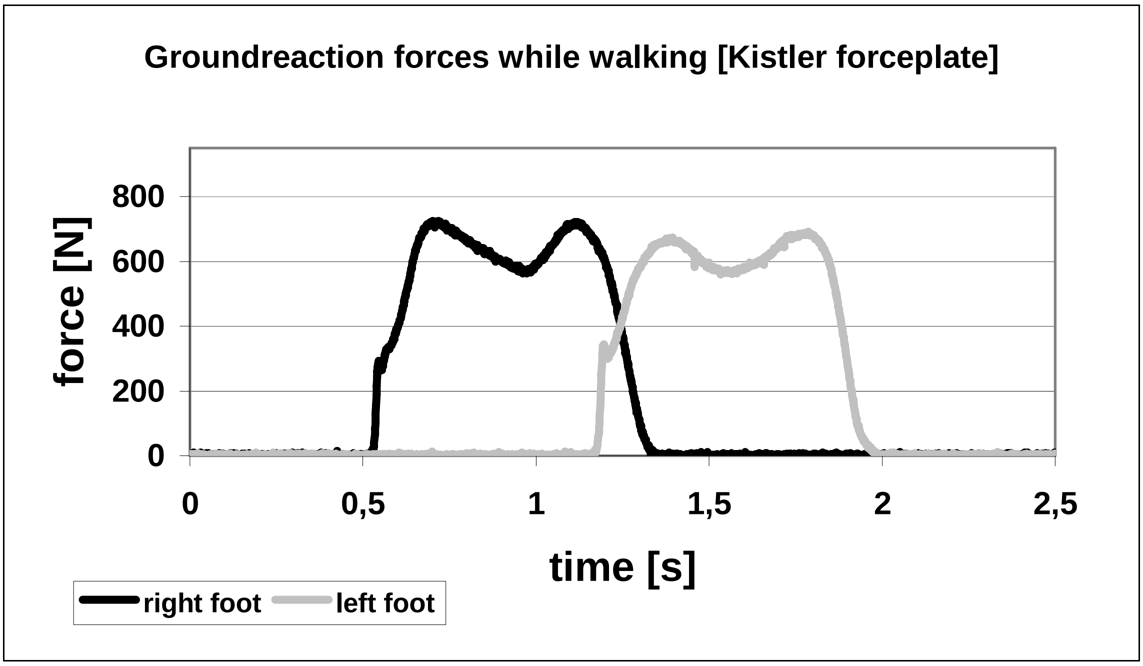

Fig. 2. Groundreaction forces while walking over a forceplate (measured by a Kistler forceplate)

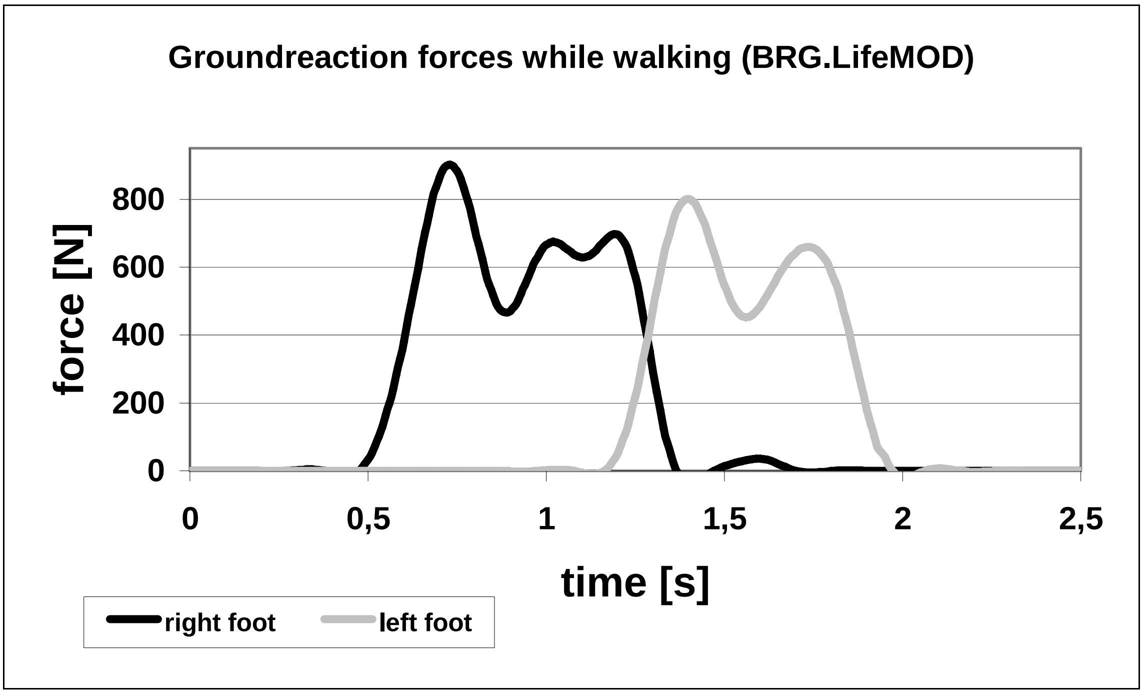

Fig. 3. Groundreaction forces while walking over a forceplate (calculated using inverse dynamic with BRG.LifeMOD™)

It can be assumed that the trait of the groundreation force in Fig. 2 and Fig. 3 presents a similar developping of the values. But it is obvious that especially the peaks of the first maximum of each step show quite big differences. So there is a variety of about 20 % comparing the groundreaction force measured with the forceplate (724 N) and the groundreaction force modelled with BRG.LifeMOD™ (900 N). The second peak of each step comprehends a satisfactorily result having a variety between the maximum of about 3.5 %.

Regarding the different points of time, when the right or left foot touches or leaves the ground, good results can be determined as well having a mean-difference of about 2.1 %.
The reason that the results in Fig. 2 and Fig. 3 show some differences, especially during the first contact of the right foot with the forceplate, can be attributed to the many settings of BRG.LifeMod™. While preparing the model there are a lot of possibilties concerning the friction between model and ground, stiffness of joints and damping the segments. This first attempt of modelling was done with the basic setting (BRG.LifeMOD™ 2005). This seems to be one possible reason for the differences expalined above.
Further researches suggest that changes in relevant settings such as friction and damping improve the results of modelling. Nevertheless, this study shows that the use of BRG.LifeMOD™ in sport science makes sense and gives another opportunity for analysing human movements.

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Supporting Free Throw Situations of Basketball Payers with Augmented Reality

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Abstract

This article presents our system for supporting basketball players with enhanced training information using augmented reality. A calibrated head mounted display guaranties the precise overlay of real environment and virtual objects. Visual information of the ideal and actual parabola and their deviation can be displayed. The setup is limited momentarily on free throw situations.

KEYWORDS: HEAD MOUNTED DISPLAY, IMAGE PROCESSING, ONLINE VISUALIZATION

Introduction

Learning situations in sports are influenced through autodidactic trail and error behavior of the athlete, instructions of the coach during the game or exercise and an offline video or measuring data analysis. Methods of augmented reality allow online visualizations of additional information. Augmented reality in live TV coverage is established for different sports (Demiris et.al., 1998). Our system allows an online augmentation in the field of view of the athlete, so that a direct and personalized feedback is possible.

Methods

Our system consists of a control unit (PC), two cameras, a head mounted display and a localization system for the detection of the line of sight of the player. The realization is subdivided into two parts. The first part is a reliable image processing for detecting the center of the ball in the camera images and calculating with that the 3D ball position. The second part is the visualization of augmenting virtual objects and their precise overlay with the real scene. Both parts will be explained in detail in the following section.

3D ball localization In the frame of this project we implemented several alternatives of ball detection in camera pictures (Pingali, Jean & Carlbom, 1998). One effective way is image subtraction of two following pictures of one sequence. The resulting picture contains mainly two basketballs (see fig. 1). After a noise suppression, an edge detection and a Hough filter the center points of the basketballs are found with subpixel precision. In figure 1 the center point of the above ball is detected automatically and marked with a crosshair.

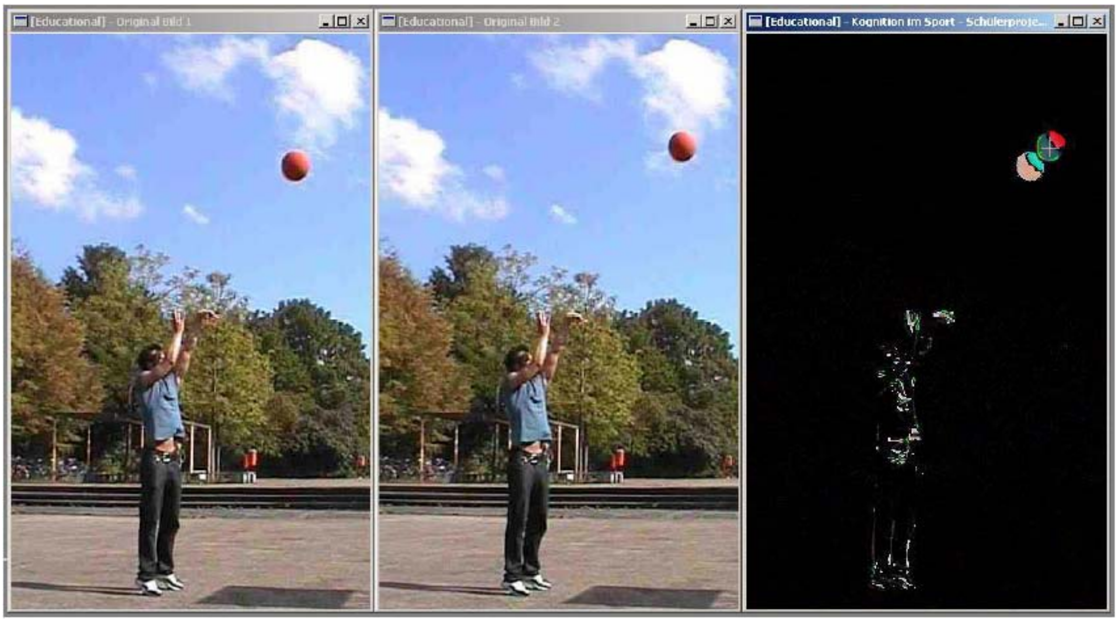

Figure 1. 3D ball localization with two following images. With the use of an image subtraction, a noise suppression, an edge detection and a Hough filter the center of the basketball is calculated (see crosshair).

The used cameras are two high speed color cameras (MC1303, Mikrotron GmbH) with a resolution of 1280x1024 pixels and a maximum full frame rate of 100 pictures per second. A Bayer filter is used for color detection. The cameras were calibrated (Hoppe, Däuber, Kübler, Raczkowsky & Wörn, 2002) and mounted in such a way that the whole area between basket and player is covered. Now, the 3D position of the ball during a throw can be calculated. The images of both cameras must be grabbed to the same moment, thus the calculated rays from the calibrated cameras lead to the proper intersection point. To calculate the parameters of the free throw parabola three points are needed. More than three points lead to a best fit parabola (see fig. 2, left picture). With these methods it is possible to determine the actual path as well as the ideal path of the basketball while taking only the strikes into account.

Visualization For an augmentation virtual objects are required. The virtual scene will be shown in the head mounted display and modeled by using the Visualization Toolkit (VTK) (Schroeder, Martin & Lorensen, 2004). The whole virtual scene consists of a ball, a basket and objects which describe the parabola (see fig. 2, right picture). The shape of the parabola is automatically updated by the calculated parameters of the 3D ball localization. For an unhindered view towards the basket specific objects are needed. To satisfy these requirements virtual guard rails are modeled (see fig. 3). The ideal parabola of the throw is visualized in this way; deviations to the actual throw are directly visible and can be corrected in the next trial. The parameters launch angle and force are now easy to verify. The used head mounted display is a virtual retinal display (Nomad, Microvision Inc.) (Pryor, Furness & Viirre, 1998) . The head mounted display is monocular, uses a laser diode with a fixed wavelength as light source and its image has a resolution of 800x600 pixels. A beam splitter enables the view through the head mounted display onto the real environment and the perception of the augmented objects. Figure 4 shows the setup. The basketball player wears the head mounted display and gets the visualization of its own parabola. The localization of the line of sight is realized by a commercial tracking system (FlashPoint, Stryker Inc.). A tracker is attached to the head mounted display and is located by the tracking system. The calibration of the head mounted display and its registration into the sports hall guaranties the precise overlay of the augmentation.

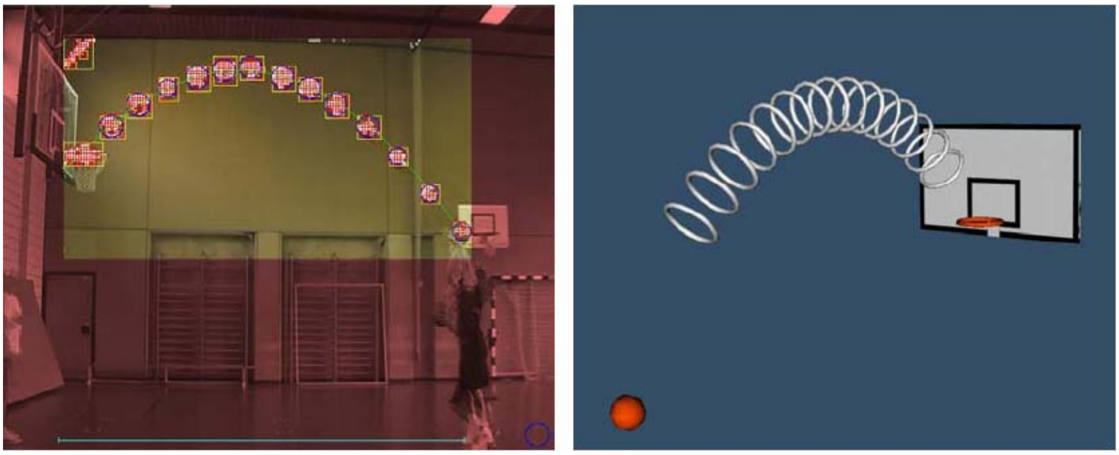

Figure 2. (left side) With several positions of the ball the calculation of the best fit parabola is possible. (right side) Example for a virtual scene, which is always needed in augmented reality.

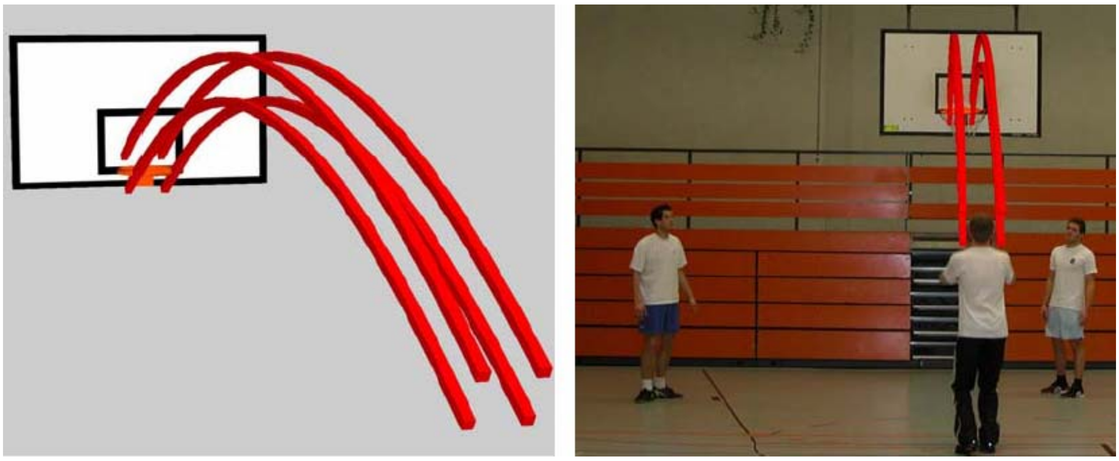

Figure 3.Visualization of an ideal parabola of a basketball throw. Virtual guard rails enable the player an unhindered view towards the basket in spite of a direct verification.

Figure 4. Use of the head mounted display in the sports hall. The line of sight is detected by a localization system. The tracker is attached to the head mounted display.

Results

The present results are promising. The detection of the basketball and different opportunities for visualization are implemented. The integration of the components allowed first experiments under real conditions in the sports hall. During a first experiment pupils had the mission to hit a virtual basketball with their real one. The virtual ball was positioned on the player's individual and ideal parabola. The throwers should concentrate only onto the visualized ball and we count a rate of strikes of over 50%.

Discussion and Conclusions

This publication presents the setup, the methods and first results of a system for supporting basketball players with methods of augmented reality. In further experiments we would like to investigate if our system has any positive influence onto the learning behavior of athletes.

Acknowledgment

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The Therapy Top Measurement and Visualization System - An Example for the Advancements in Existing Sports Equipments

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Abstract

In this paper we report on ongoing work where sensor technology and wireless networks are integrated with sports equipment to improve the utility and usability of such equipment. Our focus is on the iterative design process for a multi-disciplinary team. We show how mutual learning became a central issue for the success of the design and development.

KEYWORDS: UBIQUITOUS COMPUTING, SPORTS, SENSOR NETWORKS, USER INTERFACE

Introduction

Health is one of the most important issues in well-being of individuals as well as for a society. Sports, physical recreation and sportive games have many positive effects and can improve overall health and personal happiness. Sports have many facets ranging form fun and entertainment to physiotherapy and rehabilitation. Equipment plays an important role for sports; in many areas the equipment and technologies available shape the way we do and perceive sport. Our motivation in this project is to assess how ubiquitous computing technology can improve users' experience in sports. In particular in this paper we describe the developed system in detail.

In this paper, we report on a successfully deployed novel system in the field of sports and healthcare. It consists of several pieces of sports equipment augmented with sensors, communication and processing. By recording and monitoring exercises and by providing audio-visual feedback a new experience can be created. The technology enables users to see how they do their exercises and helps to correct and optimize their training. Monitoring and visualization of advances helps and motivates the users. Additionally the automated continuous feedback eases the task of physiotherapists and coaches as it reduces the need for human intervention. This makes it possible that the training devices can be used with less supervision and hence at lower cost.

Therapy Top – Medical Background

The therapy top is a widely used piece of equipment in the sports school that we investigated. Technically it is disk with a diameter of about 40 cm that has a rounded bottom and a flat top to stand on. There are more than 30 regular exercises that can be done with the therapy top, see the case study for details. This includes exercises for beginners and advanced users, involving one ore more feet on one ore more therapy tops. The therapy top is used in sports schools, physiotherapist practices and at home for several reasons: (1) improving the equilibrium sense, (2) improving muscle disequilibrium in legs and ankles (3) convalescence of patients after accidents and (4) muscle training in knees, backside and waist;

The difficulty in using the therapy top is to accomplish complex movements while checking that the movements are correct (e.g. the tilt angle is correct). Currently, these checks are done by a instructor at the beginning of the training who checks when the angles are correct an when not. Having continuous feedback and long-term monitoring of improvement appeared as one area where introduction of technology could help to improve the users' experience.

After injuries of the ankle, a training to improve the proprioceptive functions and to strengthen the muscles acting around the ankle is highly recommended. Due to the range of motion an ankle allows, we have certain muscles that have to be trained. These muscles are: m. tibialis anterior, m. extensor hallucis longus and m. extensor digitorum longus. These three muscles belong to a group of muscles which are used to move the toes upward (dorsal flexion). The muscles to move the toes and the foot downward (plantar flexion) are: m. gastrocnemius, m. soleus, m. plantaris, m. popliteus, m. tibialis posterior, m. flexor digitorum longus and m. flexor hallicus longus. Knowing about the anatomical structure of the ankle, we distinguish two axes of rotation. Subject to the point of application of the muscles, it provides us with the function of the muscles crossing the ankle joint. According to this they are not only responsible for dorsal and plantar flexion, but also allow for pronation of the ankle. After an injury of the ankle joint complex, the joint is normally fixed by a strong bandage or by a cast. This external stabilization leads to inactivity of the muscles surrounding the ankle. Thus it is necessary that an appropriate training program improves the function of these muscles. The right training process can show adaptive hypertrophy for these muscles.

While moving on and with the Therapy top, the effect is not only an adaptive hypertrophy but also an improvement of the control for the muscles. We call this a proprioceptive training. Proprioception is a process that helps us to control the muscle contraction. That is done while interpreting incoming information that responds to external forces. This information is given by stretch receptors in the muscles and in the ligaments. They help us to control the position of body parts, united by a joint. To stabilize the interpretation of the proprioceptive information, it is good to give another hint about the position of the body parts. This information can be given by a physiotherapist or by a computer controlled system that gives a visual or acoustical signal, going along with the real position of the body parts in an area.

System Description

The platform used for acquiring sensor data and transmitting them into the local subnet is the Particle Computer platform. Particle Computers are small wireless sensor nodes. The node's hardware comprises a communication board integrating a microcontroller, a radio transceiver (125 kbit/s, with a range of up to 50 meters), a real-time clock, additional Flash memory and LEDs a speaker for basic notification functionality. Particles especially address scenarios of high node mobility and issues of small size. The Particle communication board together with one of the sensor boards measures 15x48 mm. This is equal to the size of an AAA battery and allows unobtrusive embedding of wireless sensor technology. Particles can run of a single 1.2V battery which consumes on average 50mA. The particle computer can be extended by additional boards. With sensor and RF usage, the power consumption raises (peaks) to 80 to 100 mA. As sensor, a three-axis acceleration sensor is used.

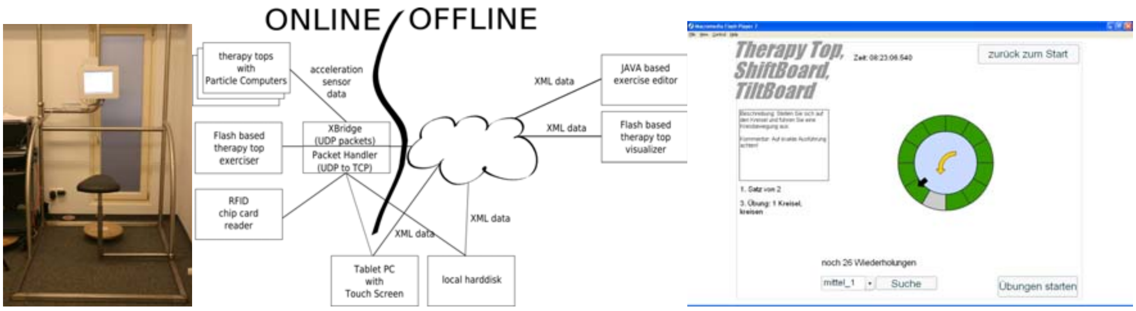

Figure 1: (a) The chair can be swung in for patients recovering from an operation and who cannot stand on a therapy top. All other users can exercise with one or two therapy tops within the steel frame. The surrounding round steel tubes provide safety in case of a stumbling or falling. For normal trainings, two therapy tops can be used at the same time, one for each foot. (b) Architecture overview. Sensor input from augmented sports devices is transmitted via RF to the infrastructure (Particle XBridge), collected and preprocessed by a UDP-to-TCP Java-based application and finally made available to the visualizing Flash application. (c) Screenshot of the GUI of the training component. The current exercise along with a minimum but training-related additional information is displayed in a clear screen layout.

The Particle is powered by two mono accumulators (2.4V, 16.000 mAH) providing a runtime of about a week at maximum power consumption. Using the microcontrollers sleep functionality when no system usage (no change in the acceleration values over a defined period of time) is detected, we derived a run-time of over a month without any maintenance. This low maintenance is especially important for the user study and the deployment. Space is not a critical requirement as in the wooden therapy top there is enough space for a cubic hole of 8x8x8 cm for batteries, sensor and measurement platform.

The pre-processed sensor data is available in the local subnet. As our development environment, Macromedia Flash, cannot directly handle UDP sockets, we developed an intermediate application. The three functionalities of it are: (1) pass the data via a TCP Socket, (2) provide a time stamped raw data storage and (3) chip card authentication.

The Flash exerciser application loads the user profiles and starts the training process. The users can review pre-recorded videos of their exercises before each exercise. The training itself is visualized in near-real time on a Tablet PC. This Tablet PC is mounted into a steal frame and positioned directly before the user at a view angle that supports good readability of the display contents. The user-system interaction is limited to RFID card authentication and touch-based interaction as input modalities. Audio-visual feedback of the exercises forms the output channel. The setup of the installed system, the system architecture and a screen shot of the Flash exerciser are depicted in Figure 1.

A graphical and simple-to-use editor allows the physiotherapist or coach to specify new exercises along with restrictions, e.g., that two therapy tops must be used and that they are to rotate contrariwise. The editor allows adding new exercises, new users and manages user-exercise program relations. This editor has been developed in JAVA and uses XML as data storage format.

The exercises are stored as XML, as is the raw sensor data from the device. This enables the trainer or physiotherapist to later review the training done by the user or patient and discover potential problems, e.g., that the patient cannot reach a certain angle with his ankle. The processed training data as well the raw sensor data are both stored on the local hard disk for later usage. The visualizing application allows coaches and trainers to review all training within a minimum time. An intuitive graphical user interface helps identifying potential deficits in the users' trainings. The RFID card reader used for authentication and access control is connected via serial line to the touch screen pc.

Conclusion and Results

In this paper we presented a successful development process for augmented sports equipment. Using an iterative design process that focuses on users' needs we augmented sports equipment with sensor technology. To create a useful system it became apparent that integration with processes and infrastructure is essential. To explore the usefulness of a system with users in a natural environment the integration as standalone prototype is not sufficient. The effort required to integrate the system with existing infrastructure and to common safety standards was much greater than the effort for building a first functional prototype. Our experience showed that having functional prototypes from the very beginning of the development is of great importance. Paper prototypes and non-functional mock-ups were used successfully but were not sufficient to get the idea of the system across to users. Especially with regard to real time functionality (e.g. visualization of the movement with the device) having a working prototype is essential to give other people on a multi-disciplinary team and users a good understanding of the design space. Having this shared understanding of the design space helps to jointly develop new ideas and finally useful systems. The therapy top system is still in use in the sports school and used during normal trainings. The system also serves as basis for several research projects in medicine. One project focuses on the effects of audio-visual training support especially for improving the fitness of children. Another project, as part of a Ph.D. study, evaluates the system during rehabilitation. We will continue our development on this system to contribute to these projects.

Acknowledgements

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Usage of an Inertial Measurement System for the Determination of Acceleration Data in Cross Country Skiing

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Abstract

The purpose of this study is to clarify the advantages and disadvantages of acceleration measurements in cross country skiing using a body mounted kinematical inertial measurement system. A high profile world cup athlete performed two test-runs in diagonal stride technique on skis and roller skies equipped with an inertial measurement system. In particular the acceleration of the athlete's centre of gravity in skiing direction is of interest with respect to the efficiency of the skiing technique. Significant differences are found between skiing and roller skiing. The main benefit of inertial measurement systems can be seen in the application in field for the measurement of complete test-runs. The weight and the mechanical characteristics of the measuring system might slightly affect an athlete adversely.

KEYWORDS: CROSS COUNTRY SKIING, INERTIAL MEASUREMENT SYSTEM, ACCELERATION

Introduction

Inertial measurement systems defined as kinematical, body mounted systems based on the measurement of inertia and consisting of accelerometers and gyroscopes were used mainly for navigational purposes in the aerospace industry. Due to the development of Micro-Electro-Mechanical Systems (MEMS) new applications in sports science are possible, too (e.g., Krueger et al., 2006; Luinge, 2002; Mayogatia et al., 2002; Williamson & Andrews, 2001). However, besides dynamometric measurements the analysis of the kinematical parameters in cross country skiing is mainly limited to the use of optical kinematical methods (e.g., Babiel, 2002; Lindinger & Mueller, 2003). Disadvantages of these methods (on infrared-, ultrasound- and video basis) can be seen in the practicability in the training process and the expenditure of time and equipment (Mayagoitia et al., 2002). In contrast, the usage of body mounted kinematical systems enables the measurement of biomechanical parameters almost without a limitation of the site. Additionally, body mounted systems require often less equipment compared to the optical methods and can also be used for real time applications.

The aim of the study is to show the general purposes of the usage of body mounted inertial measurement systems for acceleration measurements in cross country skiing. Therefore, the application for the determination of the occurring acceleration in reference to the global coordinate system on ski and roller ski will be exemplified. The acceleration at the centre of gravity expressed with respect to the global coordinate system can be considered as an interesting parameter for the analysis of the skiing technique regarding the efficiency of the skiing technique.

Methods

Data Collection

A high profile world cup athlete (30 years, 77 kg) performed two test-runs on skis and roller skis with the diagonal stride technique.

The kinematical parameters were measured by means of a 3D inertial measurement system (Xsens, Netherlands). The sensor unit includes gyroscopes, accelerometers and magnet field sensors which are used to calculate the orientation of the sensor unit with respect to the global coordinate system. In the process the magnet field data is used to compensate the growing error of measurement caused by the calculation of the rotations by usage of the rate of turn from the gyroscopes. The root mean square of the measurement error concerning the accuracy of the sensor unit's orientation is approx. 3° (Xsens, 2004). The sensor unit with a maximum measurement range of 20 m/s^2 and 300 °/s was attached close to the athlete's centre of gravity. The overall weight of the system excluding a data storage medium is approx. 400 g.

The investigation on skis was carried out at the Dachstein glacier in Austria. The athlete skied a test run with a speed of 3.8 m/s. Unlike the measurement on roller skis no wireless data transmission could be used. Therefore a data logger was stored in a backpack worn by the athlete during the test run. The adverse effect due to the additional weight was negligible according to the athlete. The test run on roller skis was carried out on a treadmill (3.8 m/s; 3° inclination) at the Institute of Applied Training Science in Leipzig, Germany. The sample rate for all test-runs was 100 Hz. Additionally, the test-runs were filmed with 50 Hz digital cameras. The adverse effects to the athlete caused by the measurement systems were almost negligible referring to the athlete.

Data Analysis

Figure 1 shows the sensor- and the global coordinate system and the vector of the acceleration of gravity. Under usage of a rotation matrix the acceleration data in reference to the global coordinate system ($a`_{measured}$) can be calculated from the measured acceleration data ($a_{measured}$). The rotation matrix is computable due to the knowledge of the orientation of the sensor unit.

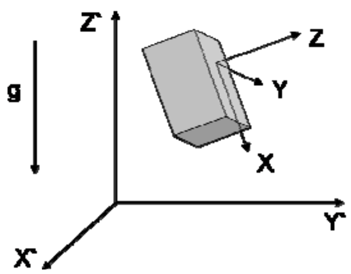

Figure 1. Illustration of the vector of the acceleration of gravity (g), the sensor coordinate system (X, Y, Z) and the global coordinate system (X´,Y´, Z´)

The acceleration caused by the movement of the athlete ($a´_{move}$) is calculated without the influence of the acceleration of gravity (equation 1) (Allard, Dimnet & Ladin, 1993).

$$\vec{a}'_{move} = \vec{a}'_{measured} - \vec{g} \quad (1)$$

The Mann-Whitney-U-Test is used for the statistical analysis of the data.

Results

Figure 2 illustrates the calculated acceleration at the athlete's centre of gravity in skiing direction for one cycle of the diagonal stride skiing technique on skis and roller skis. It can be seen that there is a positive acceleration with a maximum of approx. 15.5 m/s^2 in skiing direction on skis. The percentage of positive acceleration in skiing direction of the shown cycle is approx. 35 %. With the decrease of the acting fore in skiing direction the graph shows negative values which means a deceleration of the athlete. This is caused by a force resulting from kinetic friction, wind resistance, snow displacement resistance etc., which acts against the skiing direction (Babiel, 2002).

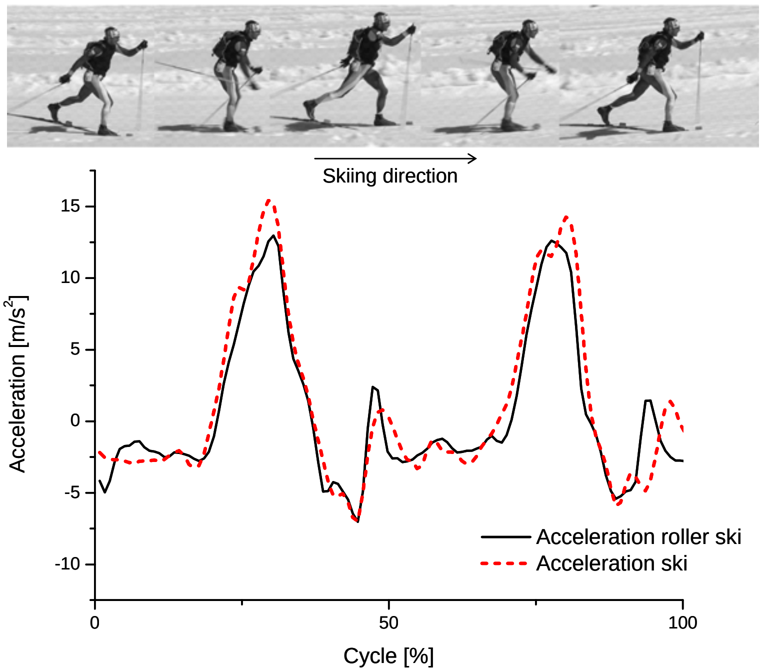

Figure 2. Acceleration at the athlete's centre of gravity in skiing direction for one cycle of the diagonal stride technique on skis and roller skis

The acceleration graphs of the diagonal stride technique on roller skis show very similar characteristics (cp. Figure 1). Table 1 presents the mean values and the standard deviation of the maximum positive acceleration in skiing direction, the corresponding percentages of the positive acceleration in relation to the cycle time and the cycle times of ten diagonal stride cycles on skis and roller skis.

Table 1. Mean value and standard deviation of the maximum positive acceleration in skiing direction, the corresponding percentages of the positive acceleration and the cycle times of ten diagonal stride cycles on skis and roller skis.

Parameter	Ski	Roller ski
Cycle time [s] (n = 10)	1,12 ± 0,02	1,17 ± 0,03
Temporal percentage of positive acceleration in relation to the cycle time [%] (n = 10)	38,32 ± 2,41	36,1 ± 3,4
Maximum positive acceleration in skiing direction [m/s^2] (n = 20)	15,24 ± 1,22	12,4 ± 0,64

There is a significant difference for the cycle time (p = .005) and the maximum positive acceleration in skiing direction (p = .000). The mean difference of the percentage of the positive acceleration between ski and roller ski is 2.23 % and is not significant (cp. Table 1). These results approve former studies (Wenger, 1982). It can be stated that the athlete must be more active on ski than on roller skis to reach the same speed due to reduced friction values. This can be realized by higher cycle frequencies and higher positive acceleration in skiing direction. Therefore the locomotion on roller skis can be seen as more efficient than on skis.

Conclusion

The study shows that the use of inertial measurement systems for the determination of kinematical parameters offers several advantages. The main advantage of the method can be seen in the application in field without a limitation of the site. Therefore, complete test-runs are recordable. The direct measurement of acceleration data is another advantage. Hence, significant differences of the acceleration in skiing direction at the athlete's centre of gravity for skiing and roller skiing with diagonal stride technique are obtainable. Due to the possible deviation of the fixation of sensors between two test-runs such results would not be accessible with conventional acceleration sensors.

Although the weight and the mechanical characteristics are negligible to the athlete, the effects may slightly influence the athlete adversely.

The combined usage of an inertial measurement system with e.g. a dynamometric measurement is considered as useful (Krueger et al., 2006). Due to an application in the technique training the system could be used to provide useful parameters (acceleration, rate of turn, angles etc.) for trainers, athletes and scientists in real time.

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An Empirical Analysis of the Utilization of New Media in Sports Science

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Abstract

The present study is intended to provide a cause and effect analysis of the degree of penetration of new media in university fields of competence and activity at the institutes of sports science and sport in Germany. The analysis focuses on the area of "Studies and Extended Studies", but also considers the fields of "Research and Development" and "Administration and Management".

KEYWORDS: NEW MEDIA, UTILIZATION ANALYSIS, SPORTS SCIENCE, STUDIES, EXTENDED STUDIES, TEACHING

Motivation

The increasing dissemination of new information and communication technologies ("New Media") in tertiary education can be explained by their utility and added values. This can be expected to produce overall ("macrostructural" – for example by reaching new target groups) added values for higher education development. This is to be distinguished from the opportunities new media bring for the technology-assisted teaching/learning process ("microstructural – for example optimization of learning achievements through adaptive learning systems). These added values are essentially based on the three dimensions of "distance" (independence of time and place), "multimediality" (integration of various media, as well as multimodal and multicodal organization) and "interactivity" (human-computer interaction and human-computer-human interaction) (Igel & Daugs, 2002).
But do (and if yes – how?) sports science professors in Germany in fact use new media in a way that enhances utility and value? Are they used in teaching, research, extended studies and administration? If not, what are the reasons for not using them? (c.f. in this context the cross-discipline analyses of Igel, Kleimann, & Meiers, 2005, Kleimann, Weber, & Willige, 2005).
In an attempt to answer these and other questions, the "New Media in Sports Science" situation analysis was conducted in the winter semester 2005/2006 by the Deutsche Vereinigung für Sportwissenschaft – dvs (German Society for Sports Science) in cooperation with the Competence Center "Virtual Saar University" at the Saarland University. The survey is oriented towards the university fields of activity "Studies and Extended Studies", "Research and Development" and "Administration and Management". The focus of the study is on the field of "Studies and Extended Studies". Similar analyses on the use of new media, albeit not with an identical subject matter, have already been carried out (c.f. Baca, 1999; Baca & Nuc, 2001; Bös & Caspari, 1998; Igel, Müller, & Daugs, 1999; Reiter, Ernst, & Olivier, 2002; Wiemeyer 1999, 2005).

Methods

The data were collected by means of a standard online questionnaire which was available on the Internet between October 30, 2005 and January 13, 2006. 297 sports science professors were invited twice by letter to participate in the online survey. The response – with 74 filled-out questionnaires – corresponded to a rate of 24.9%. The professors were also asked to encourage other teaching staff to respond. The population of the situation analysis is therefore presumably higher than the 297 who were originally approached and the response rate in fact lower.
It can be assumed that online surveys are most likely to draw a response from people with an affinity for new media. It is therefore logical to conclude that people who do not respond to the survey are probably less likely to utilize new media in their work. The deliberate media split between letter by mail and online questionnaire was intended to compensate the possible media bias – the positive corruption of the results through affinities of those responding.
The questionnaire is structured in three main categories ("Studies and Extended Studies", "Research and Development", "Administration and Management"), each with a different number of sub-categories and items. The "Studies and Extended Studies" category dominates with respect to the number and level of differentiation of the sub-categories and items. The items are for the most part conceived in the form of hybrid questions, geared to eliciting facts and knowledge. In addition, a trend prognosis for new media in sports science and the desired development is attempted with the help of an open question.

Results

During the survey period, 74 responses were received from 35 of the 62 existing and approached sports science institutes. 22 respondents came from the dvs segment "Sport-motor theory", 20 from the dvs segment "Sport pedagogy", the remaining respondents state other segments. Hence it is not possible to establish any discipline-specific tendency with respect to media affinity between representatives of natural-science or humanistic sports science sub-disciplines.

New media in Studies and Extended Studies

93.2% of the respondents claim to use new media in studies and extended studies. 63.8% asserted that they develop digital teaching/learning materials with the help of new media, although these were for the most part supplementary course materials – for example in the form of PDF or PPT files. While the majority of professors were themselves responsible for the contents of the materials, their technical realization is as a rule done in cooperation with other colleagues or entrusted entirely to these. The staff responsible for the conceptual design and technical realization were as a rule financed by the respective university. Around one third of all financing cases are financed through a mix of university and third-party resources.
On questions relating to quality management with respect to creating digital teaching/learning materials, respondents were asked to classify various topic areas according to a four-grade scale ("very important", "important", "less important", "not important"). Named with more than 90% in the categories "important" or "very important", accessibility, interface design, media didactics and learning psychology were weighted as most relevant. Sustainability was similarly classified by more than 80% of respondents. Questions relating to copyright were categorized in this way by 65% of respondents, however also judged by around 32% as "less important". Translations were considered by the majority as not important.
The utilization of new media in studies and extended studies permits new and diverse forms of synchronous and asynchronous communication. With more than 80% of the responses,

contact via email was considered as "important" or "very important". There is a tendency to give asynchronous forms of communication (e.g. email) preference over synchronous forms of communication (e.g. video conferencing). This is where the value-added dimension "distance" comes into its own through time- and place-independent communication.
In general, the level of new media penetration in studies and extended studies is already well advanced. The respondents use new media in 79% of all teaching classes, both for didactic and methodological purposes and - somewhat less frequently – for organization. The materials provided are not obligatory for students, in most cases they are used to supplement conventional teaching materials (such as textbooks). The participating university teachers assume, therefore, that only around 40% of students participating in the respective courses actually take advantage of the materials provided. This is not surprising given that the utilization of the digital teaching/learning materials is only a prerequisite for acquiring ECTS points on every fourth course.

New media in Research and Development

62% of the respondents claimed to use new media in the "Research and Development" segment. Mostly, these are used to support research work on the Internet, facilitate data evaluation and communication between members of the scientific community. Seven respondents make new media the object of their research work. 11 of the 74 respondents published a total of 51 theme-specific articles in 2005, and during the same period 17 of them held 47 lectures. From the authors' perspective, five PhDs and one post-doctoral professorial thesis in the past five years constituted relatively few qualification dissertations.

New media in Administration and Management

In administration and management, new media are used principally for information distribution or communication between students and teaching staff. 65% of respondents specified that they use new media in this field of activity. The authors believe the utilization rate in this segment is likely to be considerably higher, since the administration of student data in teaching classes is most probably handled by nearly all professors and lecturers with the help of a computer.

Development trends

The majority of the professors asked have a positive attitude towards a further increase in the utilization of new media. In assessing the desired trend, limited financial and/or personnel resources were frequently cited as a stumbling block inhibiting a rapid and comprehensive dissemination of new media (especially in studies and extended studies).

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Sport-Specific Measuring and Information Systems for Training Control

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KEYWORDS: HIGH-PERFORMANCE SPORTS, MEASURING UNIT, TRAINING CONTROL

Requirements for Sport-Specific Measuring and Information Systems in High Performance Sports

For years measuring and informations systems (MIS) have been an indispensable basis for the determination of physical abilities of elite athletes (diagnostic). However, they have been increasingly applied in training (feedback training) in particular for learning and correcting movements (technique training), as well as for the optimization of competition results e. g. in endurance sports (race optimization). In spite of the intense evolution in the field of both software simulation systems and measurement technology for the analysis of competition performance, measuring units will keep their high importance as a component of training control in future.

The application of a MIS in high-performance sports is connected with high demands on these systems. Special requirements are e. g.

- The resistance of the measuring units against extreme force actions and movement frequencies to be encountered on high performance level
- The guarantee of the reliability of the measurement results (comparability of the results, if several identical measuring units are applied; robustness against environmental impacts as temperature or humidity etc.)
- Sufficiently precise simulation of the real conditions, so that the results gained can be interpreted in terms of physical abilities (validity). That concerns both the guarantee of the sport-specific movement and the robustness against the actions of the athlete at the measuring unit.
- The devlopment of information systems, which can be used smoothly in training, diagnostic or competition.

It has to be taken into account that in most cases the individual requirements mentioned above depend on each other.

Our presentation will focus on systems simulating competition like conditions, since it is not possible to deal with all the different requirements mentioned above in this paper. This goal contains a high standard of objectivity, reliability and validity of the results gained. The following proprietary developments of recent years have been selected as examples.

Starting Block Dynamometer for Competitive Swimming

In swimming the start is of great importance, above all in short distance events. A comprehensive analysis of the start technique includes the measurement of forces occurring

during the take-off. Based on the fact that the parallel take-off was the only start technique in the past, starting block dynamometers were applied that monitored summaries of the take-off force (e. g. Härting, Zschocke, Alvermann, Wecker and Schattke 1982; Kibele 2004).
The development of the grab and track start technique (Fig. 1) requires a separate measurement of reaction forces of both feet and hands. Results of a study by an Australian team of scientists (Benjanuvatra, Lyttle, Blanksby und Larkin 2004) using divided starting block with two 2D force platforms were the first published internationally.

Figure 1. Grab and track start.

With the new starting block dynamometer the supporting forces are measured separately for every leg in vertical and horizontal direction (jump direction) and a summary for the hands in vertical direction is monitored too (Fig. 2).

Figure 2. Starting block dynamometer (left: without hood).

The force-time curves in fig. 3 clearly show the expected different course of the curve for the take-off forces of the left (front) and right (rear) leg in the grab and track start.

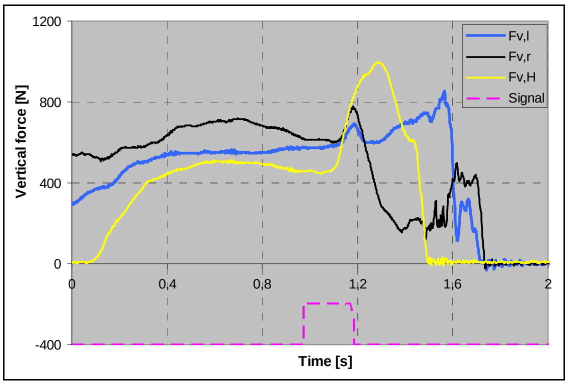

Figure 3. Vertical force-time graphs of a grab vs. a track start (Fv, l - left (front) leg; Fv,r - right (rear) leg; Fv,H - Hands).

Canoe Ergometer for Flatwater and Whitewater Canoeing and Kayaking

Canoe ergometers have been introduced as a training apparatus and for the diagnosis of specific endurance abilities in flatwater canoeing. In our case, the double-bladed paddle is connected via two ropes with a load resistor system, to the single-bladed paddle with an individual rope, in order to simulate the reaction force occurring during stroke. The quality of the simulation depends on the design of the load device.
Our canoe ergometer is a further development of Heinze's ergometer (1978). The mass of boat and athlete that has to be accelerated is represented by equivalent rotating masses. The hydrodynamic resistance of the boat is simulated by an eddy-current brake. As a result, it is possible to convert the strength effort respectively the athletes's performance into the theoretically covered distance of the canoe. Thus it becomes possible to simulate the course of races or to arrange feedback training.

Figure 4. Canoe ergometer.

The drag ropes are coiled by a retrieval device (drum with free-wheel clutch and spiral spring). The retrieval device allows frequencies up to 160 strokes per minute. These frequencies are clearly above the previous stroke frequency and correspond to the recent top performances in elite flatwater canoeing.
In tests with modern boat models in the towing tank of the shipbuilding research station Potsdam flow resistances required for the braking torque were determined. The experiments were carried out with varying towing velocities and loads.
The value of the braking force which is shown to the canoeist represents a certain speed of the boat. On a monitor mounted in front of the subject (Fig. 4, right picture) relevant parameters as boat speed, covered distance and paddle force are presented numerically and graphically. The force is measured by sensors attached to the paddle and transmitted by radio.

Measuring and Information System Ski-Jumping

The MIS ski jump "Fichtelbergschanze" has been designed for feedback training as well as to get a deeper insight into performance structure under competition-like conditions. However, it can also be employed directly in competitions (Dickwach and Wagner 2004). A chain of dynamometric platforms and the digital video recording synchronized with measuring are the essential technological basics of the system. By monitoring the force curve and the corresponding video sequence immediately before and during the take-off it the most important take-off information as direct feedback, i. g. the immediate display of essential biomechanical parameters and the synchronous presentation of force curve and video sequence (as kinegram or video clip) after the jump (Fig. 5) are possible.
The chain of platforms consists of 12 one-dimensional force platforms which are fit into a concrete tub of the final 12 m of the run-up (ski jump radius, take-off area). For measurements during winter time, a separator device can be mounted on the ski jump table.

To guarantee a high quality of the measurement the platform superstructure has to enable an independent measurement of any individual platform.

Figure 5. Kinegram and force-time graph of a take-off in ski jumping.

The determination of the radial force acting on the athlete when moving through the ski jump radius has been a special challenge. The radial force is required in order to calculate the take-off force of the jumper (lower curve) from the measured total force (upper curve). The calculation from the ski jump radius did not supply results of sufficient quality. Therefore in an additional experimental study a rigid mass was mounted on a sledge. The results which we gained in this study could be verified by the computer simulation system Alaska.

Conclusions

The application of measuring and information systems in high performance sports is connected with high requests on these systems. In general commercially available products do not meet these requests. Therefore in most cases the fifty IAT measuring units represent an advancement of commercial systems which have been customized. The IAT systems are custom-made products of specialized companies or proprietary developments.

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