THE ANN – BASED ANALYSIS MODEL OF THE SPORT TECHNIQUES

Botao Yan and Yanxi Wu
Chan National Institute of Sport Scientific Research, Beijing, People's Republic of China

The purpose of this paper was to develop an analysis model of sport techniques based on artificial neural networks. In this study, the artificial neural network (ANN) computing techniques were applied to construct sport technique analysis model. Two basic problems, the technique parameter selection and the cause-effect mapping relationship establishment, were carefully investigated. This approach was first used with shot-putt, and from 155 trials, the Overall Parameter (OP) model and the Local Parameter (LP) model were constructed and evaluated. The predictive capacity of ANN model was demonstrated to be superior to the linear regression model.

KEY WORDS: biomechanics, sport technique analysis, artificial neural networks (ANN)

INTRODUCTION: It is extremely important to ensure that the analysis methods of sport technique are adequately reliable and valid. A few researchers have been dedicated to development of mathematical and/or mechanical methods. Many researchers (Y. Takei, 1998; McPherson, 1996) have proposed the use of the hierarchical deterministic model developed by J.G.Hay in 1988. This model could partly overcome the drawbacks of arbitrarily statistical cause-effect relationships. But the work of technique analysis has always been individualized, time-consuming and could not be replicated. None of the same results of the technique evaluation and the training suggestions could be extracted from the same movement information, once different researchers had dealt with them. Thus the more accurate system was used in the technique analysis (Lapham & Bartlett, 1995; Cooper, 1991).

In this study, the objective is to program the technique analysis process and develop an analysis model of the sport techniques based upon Artificial Neural Networks (ANN). This approach was first applied to the female shot-putt technique analysis. The results have demonstrated that this approach bears the potential advantages of artificial intelligence and possesses the ability for comprehensible decision-making. Therefore, the ANN network model of technique analysis could also be taken as the base of sports technique evaluation AI expert system.

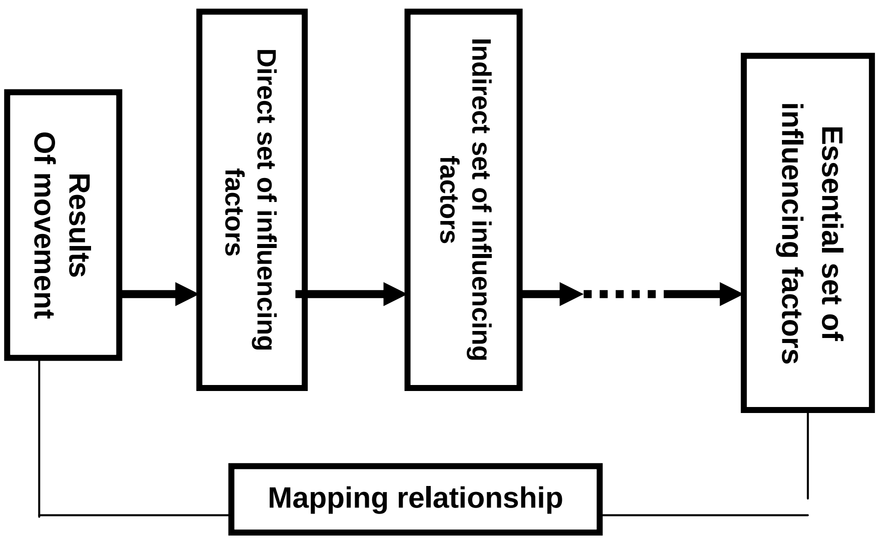

Figure 1 - The hierarchical deterministic model of the technique factors.

METHODS: Subject and test. All 31 subjects are the members of 1981-1997 Chinese national team. In official competitions 3-D video or cinematography was used (Photosonic 1PL16mm and JVC KY-19E, SVHS; 50-100 frames/sec.) and the kinematic data of 155 trials from these 31 female shot putters were collected. The range of official results is between 21.78-15.10m. The average number of trials digitized for each subject was 5 (TYF-2 digitizer and PEAK5).

The original idea from technique analysis. Most human movement is performed to achieve some objective. From the point of view of time it can be considered as a developmental course, in which the elements are linked by the behavioral purposes in sequence, as if they were in a chain. On the other hand, movements possess cause-effect properties and their effects are determined by a direct set of influencing factors. All these factors depend on the other indirect set of influencing factors, etc. (reference to Figure 1). If this reasoning is correct, finally we can get an essential set of influencing factors in one level, which might be used by coaches in athlete training. The aim of sports technique analysis is first to build up the mapping relationship of the result and the essential set of influencing factors, by which the advantages and drawbacks in an individual's movement can be diagnosed. The next-step was in athlete training, where suggestions were easily given. From the above diagram it can be seen that two key tasks must be accomplished in order to achieve an analysis of sports techniques: one is to find out the essential set of influencing factors; the other is to build the mapping relationship.

The essential set of technique factors. The human dynamic model and statistical methods were used to determine the essential set of technique factors for certain activity. The approach can be summarized as the following procedures:

1. Sum up problems to be solved, determine the analysis aim and the effect variables;
2. Determine the main links formed by segments and joints which exert or bear the main forces arising in the specialized item/activity;
3. Determine the free degrees of active joint /segment in the main links. After measurements are simplified, assign a technique variable for each free degree;
4. Build up a hierarchy model of the activity to be considered in regard to the biomechanical technique structure. The form of the hierarchy model is similar to Hay's deterministic model, but in this study, it was used simply for relating the mechanical variables describing the activity to the technique variables describing the actions of human body. From three aspects of speed, rhythm, and posture, some technique parameters can be defined for each technique variable. According to the ways of description, all the technique parameters can be divided two types: the Overall Parameters (OP) and the Local Parameters (LP). All of these parameters constitute the primary technique factor set;
5. Group the samples and implement the variance test. Compute the correlation coefficients between the effect variables and the technique parameters. Sort all technique parameters in the order of the significant level and the absolute values of correlation coefficient;
6. Set a threshold value. All the parameters whose statistical test value were above that value constituted the essential set of technique factors.

Following this procedure it is necessary to select a relatively complete set of technique parameters. This method rarely depends on the researchers' previous experiences on the technique analysis. All the technique factors in the essential set are related to the training practice, therefore they are all related to maneuverability in training.

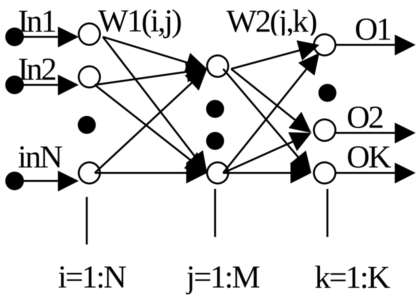

Figure 2 - Three-layered, feed-forward, and fully connected network.
(N: the numbers of input units; M: the numbers of hidden units; K: numbers of output units; W1(i,j), W2(j,k): weighted coefficient arrays.)

Neural network computing. The ANN architecture here used is a 3-layered, fully connected, feed-forward network (Figure 2). Inputs to the network are the magnitudes of the technique parameters. The signals from the output units correspond to the ANN's prediction values of effect variables. Each unit in the network receives several signals, which it processes to obtain an output, with the exception of input layer units that receive only one signal. A unit's net input (net_i) is determined by multiplying each input signal by the corresponding connection weight:

$$net_i = \sum in_{i \leftarrow j} \times w_{i \leftarrow j} \quad (1)$$

The net input is transformed by an activation function and an output signal is generated. A sigmoid activation function is used:

$$f(x) = 1/(1 + e^{-x}) \quad (2)$$

The ANNs were constructed, trained, and tested using software written to implement the standard back-propagation algorithm. Training involved multiple cycles during which interconnection weights are modified in order to reduce the difference between the network output signals (the calculated values of effect variables) and desired output signals (measured values of effect variables). This error can be measured by a square function defined in equation 3. In this study, trained ANN networks were used to learn and build up the relationship between the effect variables and the essential set of technique factors.

$$TSS = \frac{1}{2}\sum_{p=1}^{P}\sum_{k=1}^{S}\left(Y(p,k) - O(p,k)\right)^2 \quad (3)$$

P: the number of effect variables, in here equal to 2;
K: the number of samples used to train or test the model network, respectively in here equal to 134 and 21;
Y (p, k): the desired output signals (measured values of effect variables);
O (p, k): the network output signals (the calculated values of effect variables).

Table 1 The Components of Training and Testing Samples

Samples	The Number of Subjects	The numbers of Trials	trials from the same subject						Average results (m)	Result regions (m)
			one	two	thre	five	six	twelve		
Training	31	134	5	2	7	4	12	1	17.67	15.1621.78
Testing	11	21	4	4	3	0	0	0	18.70	17.0821.06

The ANN models' training and testing. Two types of technique analysis models were established to evaluate the delivery techniques of the glide-style shot-putt, the OP model and the LP model. The inputs of the OP model were 20 sieved OP technique parameters and the ones of LP model were 33 LP parameters. The outputs in these models were the horizontal and vertical shot velocities. Variants of the basic network model were obtained by incorporating differing numbers of hidden units. With the OP model, the 5,7,10,13,15 hidden units were tested, the LP model was a network with 15 hidden units.

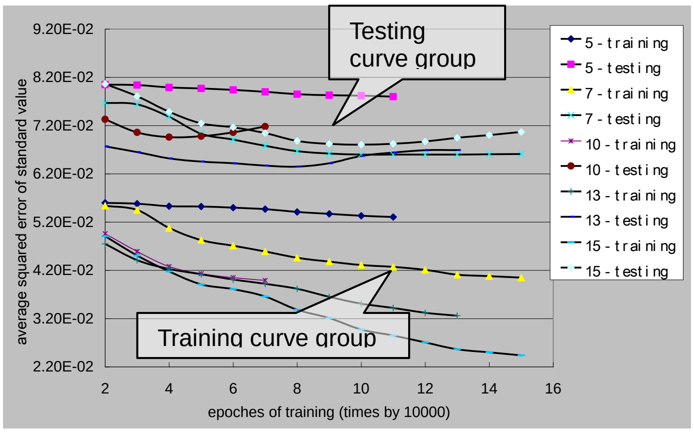

Figure 3 - Training and testing errors of all the 5 network variants of OP model change with the training manifold epochs at the vicinity of training end.

All the trials were divided into two groups: the training samples and the testing samples (Table 1). ANN models were trained with the training samples and tested with the testing samples simultaneously. The training course finished and the ANN network architecture was fixed when the testing errors refused to continue to drop.

RESULTS AND DISCUSSION: All ANN models and the variants learned to approximate more closely the desired outputs (Figure 3). The optimal network was 13-hidden-unit one, of which had the minimal training and testing errors. Thus it was defined as the network architecture of OP model. The forecasting effects of ANN model and the regression model built up from the same set of OP parameters were compared on the testing samples. The average squared errors of the release velocities Vx and Vy were 0.20 and 0.28m/s; the means of absolute errors 0.15 and 0.18m/s; the means of relative

Table 2 The Statistical Comparisons of the Predictive Errors From ANN Modeling and the Regression Modeling

		the absolute errors stat.				the relative errors stat.		
parameters		sqrt ave.	ave.	SD	max.	ave.(%)	SD	max.
training group(134 trials)								
ANN model								
Vx	m/s	0.13	0.11	0.08	0.40	1.07	0.01	3.80
Vy	m/s	0.11	0.08	0.06	0.29	1.10	0.01	3.67
Vr	m/s	0.11	0.09	0.08	0.42	0.69	0.01	3.32
release ang.	deg.	0.56	0.44	0.35	1.53	1.19	0.01	4.48
throwing dist.	m	0.28	0.21	0.19	1.03	1.18	0.01	5.84
regression model								
Vx	m/s	0.19	0.15	0.12	0.60	1.55	1.16	5.54
Vy	m/s	0.15	0.12	0.09	0.38	1.55	1.19	4.82
Vr	m/s	0.19	0.15	0.12	0.59	1.20	0.96	4.97
release ang.	deg.	0.63	0.49	0.40	1.93	1.33	1.08	5.40
throwing dist.	m	0.47	0.37	0.29	1.38	2.11	1.65	8.79
testing group £¨ 21 trials £©								
ANN model								
Vx	m/s	0.20	0.17	0.10	0.37	1.68	0.01	3.83
Vy	m/s	0.20	0.14	0.14	0.66	1.81	0.02	8.15
Vr	m/s	0.20	0.17	0.10	0.39	1.33	0.01	3.13
release ang.	deg.	0.91	0.63	0.68	2.51	1.66	0.02	6.11
throwing dist.	m	0.50	0.44	0.24	0.97	2.35	0.01	5.52
regression model								
Vx	m/s	0.25	0.20	0.15	0.48	2.01	1.52	4.72
Vy	m/s	0.31	0.17	0.27	1.26	2.15	3.29	15.52
Vr	m/s	0.29	0.23	0.18	0.65	1.79	1.42	5.22
release ang.	deg.	1.26	0.68	1.09	5.13	1.75	2.67	12.49
throwing dist.	m	0.72	0.57	0.45	1.58	3.08	2.45	8.56

errors 1.74% and 2.08%; and the maximum relative errors 8.15% and 15.52% (Table 2). The prediction of ANN model was evidently superior and compatible. The smaller error distribution index SD from the ANN model prediction also shows that nonlinear ANN model learns the intrinsic relationship more accurately than regression model.

CONCLUSION: This study had first demonstrated that it is possible to construct ANN-based analysis models of sport techniques (ANNAMT). Its predictive capacity was demonstrated to be superior to the linear regression model. ANNAMT have the automatic learning ability and "intelligence" of decision-making, which to some extent, avoids the subjectivity and empiricism in technique analysis. The method of establishing ANNAMT that was presented in this paper was successfully used to analyze the shot-putt techniques. Those who are interested in further discussion on this topic can refer to the relative paper "shot-put techniques analysis based up ANN model".

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