Comparative Analysis on the Filtering Methods of Human Kinematics Data

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Abstract: In this paper, the infinite pulse filter was analyzed in the comparative experiment method. Through the experimental analysis: In particular, the need to deal with extreme values of human motion data, to give priority to low-pass filter, the data changes are relatively smooth to consider using infinite pulse filtering. Due to the continuity of human motion and given that the data end distortion rate is higher than the initial one, it is necessary to take some extra frames after the action keyframes to reduce the error caused by end-of-sequencedistortion.

1 INTRODUCTION

Human kinematics data obtained by sports biomechanics needs to be smoothed by low-pass filter generally. In this paper, the infinite pulse filter was analyzed in the comparative experiment method, in order to understand the effect of the two methods in obtaining the human kinematics data.

2. RESEARCH METHODS

2.1 Research Object

The research object of this paper is the FIR filter, including low pass filter (fourth-order butter worth filter) and IIR filter (the standard filter function is butter worth filter).

Usually, data collected from human kinematics can be classified into three basic motion forms: linear motion, quadratic function type motion and trigonometric function type motion. In this study[1],the horizontal (X) motion data in oblique motion was used as linear signal data , the vertical (Y) motion data was used as two quadratic function type (parabolic type) signal data and the horizontal (X) motion data in the swing was used as triangular function type data.

2.2 Experimental Analysis Method

2.2.1 Experimental Data Acquisition

Two BASLER A6 high-speed cameras were used to shoot balls (tennis) respectively for oblique motion and simple pendulum motion with shooting frequency of 200 Hz, and the trajectories of balls should be closely and parallel to the vertical and flat wall with potable paper.

2.2.2 Experimental Data Processing

The high- titanium 3D V1.0C video analysis system produced by Beijing Senmiaoxin Company was used to analyze and process the image data, and dot with vibration amplitude (i.e. output frequency of 100Hz), and two kinds of filtering methods were used to smooth respectively. The differences between the results were compared after the processing of two filtering methods. The data after processing were processed with Excel 2003 and SPSS17.0.

2.2.3 Reference Standard

The image with sampling frequency of 200Hz was processed by the Adobe Photoshop CS2 9.0 software frame by frame, dotted amplitude by amplitude after image magnification. The coordinates (pixels) of the center of the ball were recorded accurately, and then converted to the actual coordinates.

Then the EXCL was used to trace point and connect lines, and then the Adobe Photoshop CS2 9.0 software was used again to obtain the coordinate of the center of the balls, which was the reference standard.

Table 1: the average deviation of data processed by different smoothing methods (units: centimeters).

Smoothing method	Projectile X (X±SD)	Smoothing method	Projectile Y (X±SD)	Smoothing method	Oscillation X (X±SD)
Low pass filtering	0.61±0.45	Low pass filtering	0.21±0.16	Infinite pulse	0.27±0.21
Infinite pulse	0.92±0.81	Infinite pulse	0.85±0.65	Low pass filtering	0.27±0.25
Original	1.52±1.29	Original	1.01±0.84	Original	0.69±0.63

The reasons for choosing it as the reference were that:

(1) It was easy to mark the center of the ball by magnifying the ball, and it is of high accuracy to identify the coordinates by the pixel coordinates.

(2) The image with acquisition frequency of 200Hz is more accurate than that of 100Hz in actual processing.

2.2.4 Error Evaluation Method

The average deviation was used to evaluate the error, that is, the average displacement difference between the position and the corresponding reference standard position in each frame was the average deviation. That is:

$$D = \frac{\sum_{i=1}^{n} |\Delta d_i|}{n} \quad (1)$$

(was the distance between the displacement and the reference standard displacement after the smooth treatment at) t_i

3 RESULTS AND ANALYSIS

3.1 Comparative Analysis on the Smoothing Errors of the Two Filtering Methods

The three types of data were processed by two kinds of filtering methods with the cut-off frequency of 6Hz. Considering the distortion rate of the end of filtering, the data at the end part was truncated, with 5 frames and 10 frames in the slanting motion (90 frames left), 10 frames and 40 frames in the oscillating motion, (390 frames left), and then the error of the result was compared to determine the effect of various filtering methods.

From table 1, it can be concluded that, in general, two kinds of filtering methods were different in dealing with the error of three kinds of signal data types, and the low-pass filtering method was better in effect. For the three kinds of signal types, the error of oblique horizontal motion (X direction) was the largest, that of the oblique vertical motion (Y motion) was the second, and that of the swing horizontal motion (X motion)was the smallest.

In the linear data signal type, the filtering effects had significant difference. In the case of the same cut frequency, the effect is that the low pass filter is better than the infinite pulse filter.

In the processing of the quadratic function type data, the effect of the low pass filter is better in the two filtering methods.

3.2 Phase Analysis

The high efficiency of IIR filter is at the expense of nonlinearity. The IIR filter with better selecting performance will be worse in phase characteristic, but the FIR filter can get a strict linear phase. So the IIR filter is used for data processing with low phase requirement. If the phase request is strict, FIR filter is better than IIR filter in performance and economy. IIR filter is used in speech processing with low phase requirements, while FIR filter is used in the processing of relative sensitive image data signals [2] .

The horizontal displacement (X direction motion) in the projectile motion, oblique vertical displacement (Y direction motion) and swing horizontal displacement (X direction) data were taken as the research objects respectively, and filtered by two different filtering methods (cut frequency of 8Hz).

In order to quantify the difference, the 90 frame data of the oblique projectile X direction motion were selected for linear programming. The programming model is as follows:

$$X = kt + C \quad (2)$$

Table 2 :Linear programming after data processing of oblique projectile X direction motion .

Linear	Model Summary		Parameter Estimates		Initial phase	Phase difference
Equation	R2	P value	C	k	-C/k	
Standard	0.983	0.000	1.218	3.019	-0.403	0.000
Low-pass	0.985	0.000	1.211	3.035	-0.399	0.004
Infinite	0.988	0.000	1.223	2.993	-0.409	-0.006

(The P value is 0.000, indicating that only the first three decimal digits are displayed after computer computing)

It can be seen from Table 2 that the correlation coefficient R2 was greater than 0.98, and the probability was less than 0.001, so the fitting of data after the processing of various methods was very significant. The comparison of slope k showed that low pass filtering was closer to the slope of reference standard and the slope of infinite pulse is less than standard. The comparison of phase difference showed that infinite pulse filtering had obvious phase retardation.

Therefore, in the case of the overall rising trend, the slope of infinite pulse filter is the least, and it can delay the change of data in the data processing.

The first 90 frame data of the oblique projectile X direction motion was selected for quadratic programming. The programming model was as follows:

$$Y = at^2 + bt + C \quad (3)$$

It can be seen from table 3 that the correlation coefficient R2 was greater than 0.99, and the probability P was less than 0.001, so the fitting of data after the processing of various methods was very significant. According to the law of the parabolic function image, it can be known that the value of the coefficient a was negatively correlated with the size of the opening. It can be concluded that the low pass filter was equivalent to the reference standard, and the opening of the infinite pulse was slightly larger than the standard.

Table 3 :Quadratic programming after data processing of oblique projectile X direction motion.

Quadratic	Model Summary		Parameter Estimates			Initial phase	Phase difference
Equation	R2	P value	C	b	a	-b/2a	
Standard	0.995	0.000	2.127	-0.197	-4.49	-0.019	0.000
Low-pass	0.995	0.000	2.121	-0.167	-4.523	-0.014	0.005
Infinite	0.997	0.000	2.122	-0.222	-4.409	-0.025	-0.006

(The P value is 0.000, indicating that only the first three decimal digits are displayed after computer computing)

Therefore, in the case of the overall downward trend, the opening of the image was downward while the opening of the infinite pulse filter was the smallest. As a result, the downward trend was slower and the phase was delayed, so the change of data was delayed too.

The first 400 frames data of the oblique projectile X direction motion was selected for nonlinear programming. The programming model was as follows:

$$X = A\sin(bt + c) + d \quad (4)$$

Table 4: Nonlinear programming after data processing of wobble X direction motion.

Trigonometric	Model Summary		Parameter Estimates				Initial phase	Phase difference
Equation	R2	P value	A	b	c	d	-c/b	
Standard	1	0.000	0.236	-2.964	3.051	2.619	1.029	0
Low-pass	0.999	0.000	0.237	-2.98	3.078	2.619	1.033	0.004
Infinite	0.999	0.000	0.236	-2.98	3.076	2.619	1.032	0.003

(The P value is 0.000, indicating that only the first three decimal digits are displayed after computer computing)

It can be seen from table 4 that the correlation coefficient R2 was greater than 0.998, and the probability P was less than 0.001, so the fitting of data after the processing of various methods was very significant. The value of the parameter B in the table showed the frequency of the signal data after various processing, and it can be seen that the difference between the low pass filter and the infinite pulse was small. The comparison of phase difference showed there is little difference in the whole, and the infinite pulse was slightly backward than the low pass filter phase.

3.3 Endpoint Distortion Analysis

The data after the processing of filtering and smoothing was distorted[3], and the related research has confirmed that the distortion rate at the end of the data sequence was larger than that at the beginning of the data sequence [4]. We are discussing the degree of the distortion at the end now. The degree of distortion was measured by an average deviation of D in this experiment. The original data of oblique horizontal motion (X motion), oblique vertical motion (Y motion) and swing horizontal motion (X motion) was filtered by various filtering methods (cut frequency of 8Hz), and then compared with reference standard data. The average deviation between the first 10 frames and the last 10 frames was selected to compare.

Table 5 :Comparison of beginning and end distortion after filtering processing (unit: cm).

	Low-pass	Infinite pulse	Original
First 10 frames of oblique X	0.07	0.43	0.42
Last 10 frames of oblique X	0.08	0.45	0.38
Distortion difference	0.01	0.02	-0.04
First 10 frames of oblique Y	0.09	0.48	0.41
Last 10 frames of oblique Y	0.10	0.50	0.39
Distortion difference	0.01	0.02	-0.02
First 10 frames of swing X	0.11	0.52	0.38
Last 10 frames of swing X	0.11	0.54	0.37
Distortion difference	0	0.02	-0.01

It can be seen from table 5 that the degree of distortion of the beginning and the end was ranked according to size as infinite pulse filter and low pass filter. In the case that the filtered data was distorted at the beginning of the original data sequence larger than the end of the sequence, the distortion of the end of the two filtered data was greater than the beginning, and the distortion of low pass filter was the smallest.

3.4The Influence on the Extremum

Generally, smoothing the data will have an effect on the maximum and minimum[5]. Over smoothing will weaken the extreme value, that is, the minimum value will increase and the maximum value will decrease. The higher the truncation frequency is, the more extreme the value is weakened. Different processing methods have different effects on the extremum. In this study, these two filtering methods (cut frequency of 8Hz) were used to compare the extreme values obtained by smoothing the oblique Y motion and the swing X motion data with extreme values and the reference extreme values.

Table 6 The influence of different filtering methods on the extremum (unit: meter).

Data	Method	Standard	Low pass	Infinite
Oblique Y	Maximum	2.101	2.099	2.09
Swing X	Maximum	2.854	2.854	2.853
	Minimum	2.383	2.383	2.385

(Due to only the Oblique Y motion had a maximal value, and the swing X motion had maximum and minimum in the data collected, so only the three extremums were discussed)

It can be seen from the data in Table 6 that the data of oblique Y motion reduced after the processing of low-pass filter and infinite impulse filter, and reduced a lot after the smoothing of infinite impulse; as for thedata of swing X emotion, the maximum and minimum was equal to the standard after the processing of low pass filter, the maximum after the processing of infinite impulse filter became small and the minimum became large.

In the two filtering methods, the extremum-keeping of the low pass filter was stronger and the infinite impulse filter weakened the extremum greatly.

4 CONCLUSIONS AND SUGGESTIONS

Through the above analysis, the following conclusions and suggestions are obtained:

4.1 Conclusions

In general, no matter what data is processed, the performance of low-pass filtering is better; when dealing with trigonometric data, there is basically no difference between low-pass filtering and infinite pulse filtering.

Low-pass filter can maintain a good phase, infinite pulse filter phase delay more obvious changes more slowly, the mutation of the data has a stabilizing effect.

There are data distortion problems in both filters. Generally, the distortion rate of the filter results at the end of the sequence is slightly larger than the distortion rate at the beginning.

Under the same cut-off frequency, the low-pass filter has the ability to maintain the extreme value, and the infinite pulse filter to the extreme weaken.

4.2 Suggestions

In particular, the need to deal with extreme values of human motion data, to give priority to low-pass filter, the data changes are relatively smooth to consider using infinite pulse filtering.

Due to the continuity of human motion and given that the data end distortion rate is higher than the initial one, it is necessary to take some extra frames after the action keyframes to reduce the error caused by end-of-sequence distortion.

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