Monitoring method of use frequency of sports electronic products based on non-uniform sampling

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Abstract: In order to overcome the problems of slow response speed of monitoring instruction, poor anti-interference effect and large error of monitoring results, this paper proposes a frequency monitoring method for sports electronic products based on non-uniform sampling. The frequency information of sports electronic products is collected by non-uniform sampling, and the noise reduction processing is carried out by using the average operator filter to obtain reliable output results. Finally, the monitoring procedure is started to complete the monitoring of the frequency of sports electronic products. The experimental results show that the response time of the monitoring instruction is 3.0–3.8 s, the error of the monitoring results varies from 4.2% to 4.7%, which proves that the method has faster response speed and higher effectiveness to the monitoring instruction, and has stronger anti-interference effect in the monitoring process, which indicates that the method has higher application advantages.

Keywords: sports electronic products; frequency of product use; frequency monitoring; non-uniform sampling; average operator filter.

Reference to this paper should be made as follows: Wei, Y. (2022) 'Monitoring method of use frequency of sports electronic products based on non-uniform sampling', *Int. J. Product Development*, Vol. 26, Nos. 1/2/3/4, pp.168–178.

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1 Introduction

With the development of electronic technology, it has been widely used in more and more fields. Especially in the field of sports, with the increase in the use of sports electronic products, sports and events are gradually specialised, strict and scientific. It can be said that effective sports electronic products can better serve users and provide better sports experience for users (Yan, 2019; Tan, 2018). Monitoring the use frequency of sports electronic products can help people grasp the market trend of sports electronic products and understand the future development direction. Therefore, it is very important to design an effective monitoring method for the use frequency of sports electronic products (He, 2017).

In Li et al. (2017), a collection and monitoring method of product usage frequency based on adaptive sampling and AD7606 was designed. This method firstly use STM32F407 equipment, electronic products in use process by taking the photoelectric pulse signal to calculate the vibration frequency, on this basis, through parallel operation, the transmission of vibration frequency is calculated to AD7606 equipment port, after finished product use the signal acquisition process, through the implementation of the discrete Fourier transform to calculate the vibration signal amplitude and phase Angle, using a serial port to transmit the calculation results in the first place machine operation, combined with the data analysis process to monitor products use frequency. However, it is found in practice that this method has the problem of slow response of monitoring instruction to some extent. Wei (2018) designed a collection and monitoring method of product usage frequency based on one object one code. This method will sports electronic products use frequency monitoring work is divided into three parts, respectively product warehousing, logistics and product users, each sports as a way of using a material yard electronic product design unique qr code information, the user is in when to buy or use products need to scan the product mark information, be swept through collecting product code, can complete electronic products use frequency of monitoring in sports. However, it is found in practical application that this method has the problem of poor anti-jamming effect in the monitoring process to some extent. Lu et al. (2020) design a method of frequency utilisation road measurement based on digital cluster system. The method uses the digital cluster system, focuses on the collection process of electronic products frequency utilisation rate, collection equipment requirements and road test process design, on the basis of ensuring the use of frequency information collection amount, through data analysis and calculation to complete the use of sports electronic products frequency monitoring. However, it is found in practical application that this method has the problem of large error of monitoring results to some extent.

In view of the problems existing in traditional monitoring methods, such as slow response speed of monitoring instructions, poor anti-interference effect and large error of monitoring results, this paper designs a frequency monitoring method for sports electronic products based on non-uniform sampling. The design ideas of this method are as follows:

1. The use information of sports electronic products is collected by means of non-uniform sampling, and the noise reduction processing is carried out by means of the average operator filter to reduce the error of monitoring results,
2. Start monitoring procedure and complete monitoring of the frequency of sports electronic products.
3. The experimental results show that the proposed method is compared with the traditional method, which takes the time-consuming response of monitoring instructions, anti-interference effect of monitoring process and error of monitoring results as experimental indexes.

2 Frequency monitoring of sports electronic products based on non-uniform sampling

2.1 Collection of usage frequency information based on non-uniform sampling

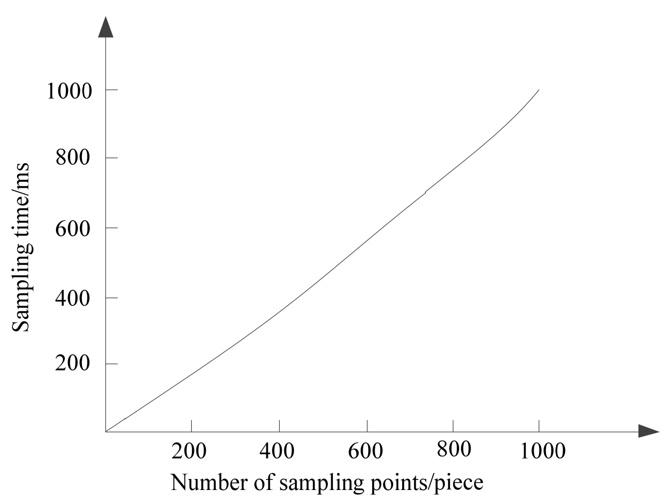
There are many kinds of non-uniform sampling. Generally speaking, as long as the sampling interval is not constant, it can be considered as non-uniform sampling, but it does not have special performance for most non-uniform sampling. The research of non-uniform sampling is especially used in two cases: random sampling and pseudo-random sampling. The selection of each sampling point in random sampling is completely random and ideal non-uniform sampling; the selection of each sampling point in pseudo-random sampling is the selected pseudo-random number.

Because the frequency of sports electronic products is not fixed, in order to improve the effectiveness of frequency monitoring, non-uniform sampling method is used to collect the frequency information of sports electronic products.

Sampling is the first step in the process of digital signal analysis and processing. Almost all digital signal processing methods are based on sampling data. Once there is a problem with the sampled information, it will be difficult to process the sampled information effectively (Fu et al., 2019; Xiong et al., 2019). Therefore, the reliability of sampling process and its results is very important. As the monitoring process of sports electronic product usage frequency is a complex process including information collection, information transmission, cross domain analysis and so on, this paper considers the use of non-uniform sampling method to collect sports electronic product usage information.

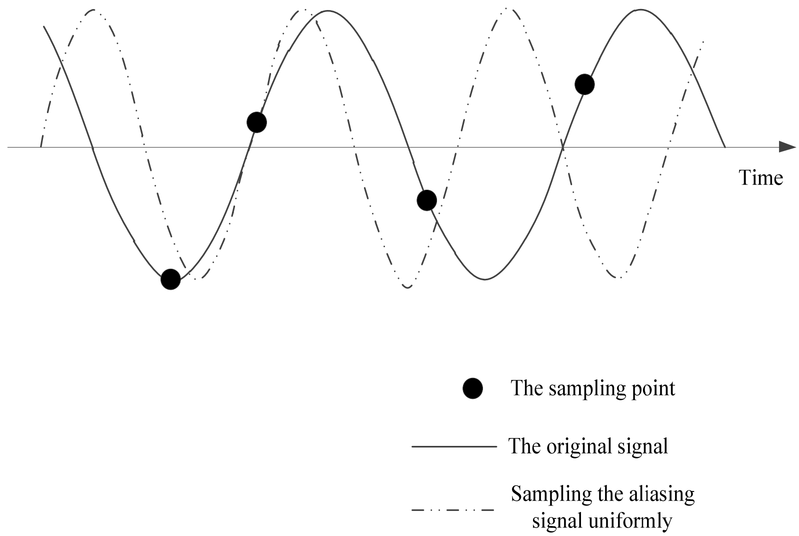
In the process of non-uniform sampling, the number of sampling points is shown in Figure 1.

Figure 1 Number of sampling points in non-uniform sampling



The waveform of non-uniform sampling time domain aliasing signal is shown in Figure 2.

Figure 2 Schematic diagram of non uniform sampling time domain aliasing signal



Firstly, the time of non-uniform sampling is set as $t_n = \partial_n + u$, where ∂ represents the time interval of uniform sampling and *u* represents the random variable from the time Angle. If *u* does not exist, then the collected result is the uniformly sampled signal, and the spectral information of the sampled signal can be determined by the fast algorithm of discrete Fourier transform. However, for non-uniformly sampled signals, it is difficult to define the spectral information of the sampled signals directly through the fast algorithm of discrete Fourier transform because the sampling interval is not clear and fixed from the perspective of time. To solve this problem, the least square method is considered in this study to realise non-uniform sampling.

On the basis of exploring the basic theory of Fourier transform, we know that a continuous signal can be obtained by the superposition of a certain number of sinusoidal signals (Wang and Lian, 2020; Sun et al., 2017). Therefore, suppose that a continuous, stationary signal $p(t)$ is expressed in the form as follows:

$$p(t) = \sum_{i}^{N} A_i \sin(2\pi f_i t + \theta_i) \tag{1}$$

In Formula (1), A_i represents the respective amplitudes of different frequency components in the signal segment, f_i represents the frequencies of different frequency components in the signal segment, θ_i represents the phase of the signal segment, and *N* represents the number of frequency components in the signal segment.

On this basis, non-uniform sampling is carried out for signal $p(t)$, and then a set of non-uniform sampling results $q(tn)(n = 1, 2, \cdots, N)$ are obtained, where *tn* represents the time of non-uniform sampling and *N* represents the number of frequency components of the signal in this segment, which can also be regarded as sampling points (Wang et al., 2018a; Wu and Ma, 2020). Then, according to the least square method and combined with the results of $q(tn)$, the parameters of each frequency component in the continuous and stationary signal are calculated, and the results are shown as follows:

$$E(A,\theta)=\sum_{n=1}^{N}\left(q(tn)-\sum_{i}^{N}A_i\sin(2\pi f_i t+\theta_i)\right)^2 \tag{2}$$

In Formula (2), $A=[A_1,A_2,\cdots,A_N]$, $\theta=[\theta_1,\theta_2,\cdots,\theta_N]$.

At this point, let false G represent an $N\times 1$ dimensional vector, H represent a $2N\times 1$ dimensional vector, I represent an $N\times 2N$ dimensional vector, and then put it into Equation (2), we can get:

$$E'(A,\theta)=G-HI_2 \tag{3}$$

On this basis, the least square method is used to expand and solve Equation (3), so as to obtain the following formula:

$$H=(I^tI)^{-1}(I^tq) \tag{4}$$

In the above various results, H contains the parameters of each frequency component in the continuous and stationary signal. G represents non-uniformly sampled information, and I contains all frequency components in the signal (Wang et al., 2018b; Liu et al., 2019; Chen, 2018). If the frequencies of each component in the signal segment are known, then the parameters of the signal segment can be obtained by Formula (4). In general, we think that the value of N is infinite, so the frequency difference between the components is small.

Through the above process, the non-uniform sampling of the use frequency of sports electronic products is completed.

2.2 Monitoring of the use frequency of sports electronic products

On the basis of the non-uniform sampling of the use frequency of sports electronic products, combined with the anti-interference processing process, the effective monitoring of the use frequency of sports electronic products is realised.

In order to avoid the interference of environmental noise to the monitoring results as much as possible, this study used the average operator filter to carry out noise reduction processing on the use frequency information of sports electronic products collected by non-uniform sampling before the formal implementation of monitoring. Firstly, the average operator filter model is expressed as follows:

$$W=\sum_{j=1}^{m}\frac{\alpha}{\delta_j}d(c_j) \tag{5}$$

In Equation (5), m represents the number of average operator filtering Windows, c_j represents the central value of the filtering window set, $d(c_j)$ represents the gray value of the window set, α represents the fuzzy evaluation value, and δ_j represents the scale parameter.

On this basis, it is assumed that there is interference information V in the monitoring environment, that is to say, there is interference information V at different filtering frequencies. Then, the interference information is processed in the way of balanced processing, and the output result is as follows:

$$S_V(T) = \frac{\int_{-\infty}^{+\infty} \mu WH(T,V)\,dV}{\int_{-\infty}^{+\infty} WH(T,V)\,dV} \tag{6}$$

In Formula (6), T represents all the time in the monitoring process, H represents the use frequency information of sports electronic products to be monitored, and μ represents the information transmission speed. According to Formula (6), the use frequency information of sports electronic products after the abnormal information is proposed can be obtained to improve the reliability of monitoring results.

On the basis of non-uniform sampling and anti-interference processing of the frequency information of sports electronic products, a specific monitoring process is designed.

After the start of the monitoring program, give the monitoring instructions and determine if any sports electronic products are being used. If so, the time and state of the use of sports electronic products are recorded, and the recorded information is saved to the real-time database. On this basis, in the way of regular monitoring, query statistics and feedback sports electronic products equipment name, use date, use the total time and the number of use. Specific monitoring steps are as follows:

Step (1): Start the monitoring procedure to determine if any sports electronic products are being used. If yes, perform step (2), otherwise end the monitoring procedure.

Step (2): Collect the use frequency information of sports electronic products by means of non-uniform sampling.

Step (3): The average operator filter is used to carry out denoising processing on the collected frequency information of sports electronic products, so as to obtain reliable output results.

Step (4): Analyse and record the time and status of sports electronic products, and save the recorded information to the real-time database.

Step (5): Update the total time used by sports electronic products.

Step (6): In the way of regular monitoring, query statistics and feedback sports electronic products equipment name, use date, use of the total time and the number of use, and its statistics to the database.

Step (7): Complete the monitoring of the use frequency of sports electronic products.

3 Experimental comparison and result analysis

3.1 Experimental design

In order to verify the practical application performance of the frequency monitoring method of sports electronic products based on non-uniform sampling, the following simulation experiments are designed.

The experimental environment is set as follows: the experimental host processor is i9-9980XE (memory is 256TB), and the experimental operating system is windows 10. In order to ensure the uniqueness of the experimental environment, the number of experiments is modulated to 300 times.

The data used in the experiment are all from the 'REST sports database', from which the hardware parameters, product sales information and use information of sports electronic products are obtained. Based on the above data, a virtual simulation environment is constructed by using MATLAB simulation software, so as to effectively monitor the use frequency of sports electronic products.

3.2 The experiment indicators

In order to avoid the single experimental results, the method proposed is compared with Li et al. (2017) and Wei (2018) with the time-consuming response of monitoring instructions, anti-interference effect of monitoring process and error of monitoring results as experimental comparison indexes.

1 *Time consuming of monitoring command response*: the response time of monitoring instruction will affect the response speed of different methods to the monitoring instruction. The less response time, the faster the response speed of monitoring method to monitoring instruction; conversely, the more time-consuming the response, the slower the response speed of monitoring method to monitoring instruction.

2 *Anti-interference effect of monitoring process*: because of the environmental interference in the monitoring process of sports electronic products, it will affect the final monitoring results. Therefore, the anti-interference effect of monitoring process is verified. Step disturbance component is added in the experiment. By analysing the stability of monitoring command output, the anti-interference effect of different monitoring methods is analysed. The higher the stability of the output of monitoring instruction, the better the anti-interference effect of the monitoring process is.

3 *Error of monitoring results*: the index can directly reflect the effectiveness of different methods. The lower the error of monitoring results, the higher the effectiveness of the monitoring method.

3.3 Experimental results and comparative analysis

3.3.1 Comparison of monitoring instruction response time

First, the monitoring instruction response time of different monitoring methods was counted, and the results are shown in Table 1.

By comparing the results in Table 1, it can be seen that after the application of method of Li et al. (2017), the monitoring instruction response time varies between 3.7 s and 4.9 s with the increasing number of tests. After the application of method of Wei (2018), the monitoring instruction response time varies between 4.7 s and 7.2 s with the increasing number of tests. However, with the application of method in this paper, with the continuous increase of the number of tests, the monitoring instruction response time varies between 3.0 s and 3.8 s and shows a slight increase trend.

Table 1 Statistical results of monitoring instruction response time of different monitoring method(s)

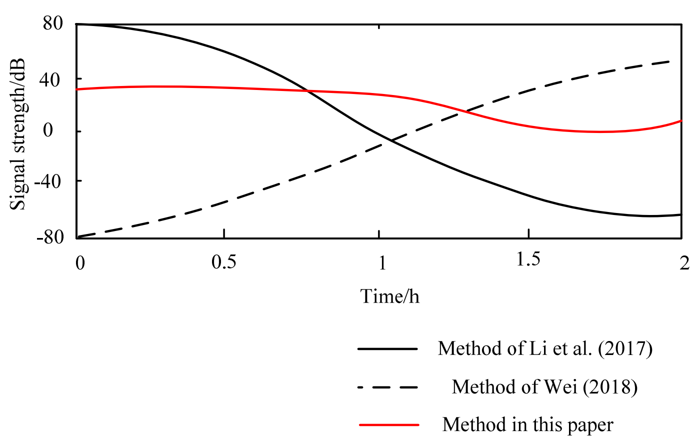
Number of experiments/time	*Method of Li et al. (2017)*	*Method of Wei (2018)*	*Method in this paper*
50	4.7	5.8	3.0
100	4.9	4.7	3.1
150	4.5	6.5	3.2
200	4.7	7.2	3.5
250	3.7	5.3	3.6
300	3.8	6.4	3.8

Through the above comparison, it can be seen that the monitoring instruction response time of method in this paper is less, indicating that the method has a faster response speed to the monitoring instruction.

3.3.2 Comparison of anti-interference effect in monitoring process

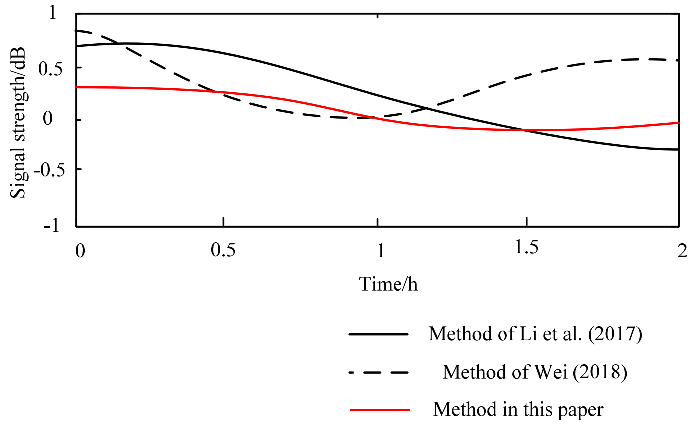
In order to verify the anti-interference effect of different products using frequency monitoring method in the monitoring process, the step disturbance component is added in the experiment to implement signal disturbance to the monitoring process, and then the influence of the disturbance component on the output stability of the monitoring command under different monitoring methods is analysed in the initial stage and mid-term stage of the monitoring command. The comparison results of anti-interference effect of different monitoring methods are shown in Figure 3.

Figure 3 Comparison of anti-interference effects of different monitoring methods in the monitoring process



(a) The initial stage of issuing the monitoring instruction

Figure 3 Comparison of anti-interference effects of different monitoring methods in the monitoring process (continued)



(b) Monitoring order issued in the middle stage

It can be seen from the comprehensive analysis results shown in Figure 3 that, in order to overcome the influence of step disturbance component on the monitoring process, different methods produce varying degrees of adjustment amplitude fluctuation. But by contrast, both in monitoring instructions are the initial stage, and in monitoring instructions are the intermediate stage, the method in this paper, the regulation of the magnitude of the range are less than two traditional methods, explain the step disturbance component of disturbance degree is lower, which proves that the method in this paper has stronger anti-interference monitoring process effect, allows monitoring the stability of the command output is higher.

3.3.3 Error comparison of monitoring results

Finally, the application performance of method in this paper, method of Li et al. (2017) and method of Wei (2018) is compared with the error of monitoring results. The error statistical results of the three methods are shown in Table 2.

Table 2 Statistical results of monitoring results error of different monitoring methods (%)

Number of experiments/time	*Method of Li et al. (2017)*	*Method of Wei (2018)*	*Method in this paper*
50	8.6	6.9	4.7
100	8.8	5.8	4.6
150	8.4	7.6	4.5
200	8.6	8.3	4.2
250	9.6	6.4	4.3
300	9.7	7.5	4.4

By comparing the results in Table 2, it can be seen that after the application of method of Li et al. (2017), with the increasing number of tests, the error of its monitoring results varies between 8.4% and 9.7%. With the application of method of Wei (2018), the error of its monitoring results varies between 5.8% and 8.3% with the increase of the number of tests. However, with the application of method in this paper, the error of the monitoring results varies between 4.2% and 4.7% with the increasing number of tests, and presents a slight trend of first decrease and then increase.

Through the above comparison, it can be seen that the monitoring result error of method in this paper is lower, indicating the higher effectiveness of this method.

To sum up, through the contrast experiment shows that this study design based on non-uniform sampling sports electronic products use frequency of the monitoring method of monitoring command response time from 3.0 s to 3.8 s change, monitor changes the result error is between 4.2% and 4.7%, which proves that the method in this paper, for monitoring the response of the instruction is faster, more efficient, and it has stronger anti-interference effect, monitoring process can make monitoring the stability of the command output is higher. Therefore, the non-uniform sampling based sports electronic products frequency monitoring method has more application advantages.

4 Conclusion

In view of a series of shortcomings of traditional methods for monitoring the use frequency of sports electronic products, this paper designs a new method for monitoring the use frequency of sports electronic products based on non-uniform sampling results. The performance of the method is verified theoretically and experimentally. The improved method has higher monitoring accuracy and response speed in the use frequency monitoring of sports electronic products. The experimental results show that the response time of the monitoring command varies from 3.0s to 3.8s, and the error of the monitoring result varies from 4.2% to 4.7%. It is proved that this method has faster response speed and higher effectiveness to the monitoring instructions, and it has stronger anti-interference effect in the monitoring process. Putting it into use can quickly and reliably complete the efficient monitoring of the use frequency of sports electronic products.

Acknowledgements

This work was supported by Guangxi Provincial Education Department Foundation under grant No. 2019JGB488, "Research on Application of Micro-lesson Video in the Teaching of College Students' Physical Health Test Project".

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