Accuracy evaluation method of sports bracelet monitoring based on grey comprehensive clustering

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Abstract: In order to improve the accuracy and timeliness of evaluation results, this paper designed an accuracy evaluation method of sports bracelet monitoring based on grey comprehensive clustering. Firstly, the iterative algorithm is used to process the sports bracelet data to avoid the loss or abnormality of data affecting the quality of evaluation results and evaluation time. Then, a fuzzy comprehensive evaluation model is established to reflect the prominent influence of different evaluation indexes, and the relative membership degree of evaluation indexes is calculated. Finally, grey comprehensive clustering algorithm is used to optimise the fuzzy comprehensive evaluation model to complete the evaluation of the monitoring accuracy of the sports bracelet. Experimental results show that the maximum accuracy of this method can reach 83%, the minimum time is only 0.8 s, and the amount of data effectively processed reaches more than 1600 MB, which proves that the design expectation is effectively realised.

Keywords: grey comprehensive clustering; sports bracelet; monitoring accuracy; monitoring data; relative membership.

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1 Introduction

At present, with the continuous development of intelligent technology, wearable intelligent devices have been widely used (Ash et al., 2020). Among them, sports bracelet with its convenient, compact, complete functions and other characteristics by people's love (Sam et al., 2021). Sports bracelet has the function of monitoring sports state, sleep state and so on, and has a certain auxiliary role in monitoring human health. After a period of development, sports bracelets gradually improve the functions, its sales market is also in a relatively stable state, but in practical use, also exposed some problems, such as inaccurate monitoring data, data update is not timely and other problems (Bai et al., 2019). Therefore, it is necessary to evaluate its monitoring effect as the basis for functional improvement if it wants to bring its maximum functional effect into play.

Hao et al. (2019) proposed the validity evaluation method for monitoring the amount of physical activity of sports smart bracelet, and collected relevant data in the form of data collection, such as the wearer's exercise data, exercise energy consumption, body state and so on. In order to ensure the validity of the data, EMBASE and other databases are used to screen the required data and the wearer's human activity indicators are obtained through data sorting, and finally the monitoring results are obtained. Analysis of the research results shows that the monitoring results obtained by this method can obtain different types of index data, but there is a certain deviation in the accuracy of the index, which will lead to misleading to relevant personnel when analysing the monitoring results. Huang (2018) proposed an evaluation model of physical health monitoring effect based on index classification and quantification, selected the physical health evaluation index system of the investigated objects, mapped multiple indexes and transformed the single index problem into multi-index optimisation, so as to obtain the optimal solution. Then the evaluation indexes are graded, and the preference convergence optimisation is carried out to obtain the final evaluation result of monitoring effect. The results show that the evaluation model can comprehensively evaluate the results of physical health monitoring and evaluate different types of monitoring means, which has the advantages of strong applicability. However, due to the large amount of data to be processed, the evaluation method is not effective in processing large amount of data. Li et al. (2015) proposed an evaluation method for wearable devices based on quality characteristics, which evaluated the effectiveness from the perspective of device quality. The results showed that this method could effectively evaluate the use effect of devices, but the evaluation time was long and the efficiency needed to be improved.

Since there are many problems in the application of smart devices and the evaluation results will be affected, this paper takes the sports bracelet as an example and proposes a method of monitoring accuracy evaluation based on grey comprehensive clustering. On the basis of the normalisation of the index, the grey comprehensive clustering of the index can avoid the jumping phenomenon of the evaluation index value, so as to improve the accuracy of the evaluation result. The main research route of this method is described as follows:

1) After collecting sports status data, energy consumption data, body status data and other sports bracelet data, the collected original data are used to recurse new data, so as to avoid data loss or abnormality affecting the quality of evaluation results and evaluation time;

2) According to the nonlinear characteristics of each evaluation index and the relative membership degree of fuzzy judgment index, the prominent influence of different evaluation indexes is reflected by establishing comprehensive index relations to avoid the impact of the accuracy of evaluation results due to the jump phenomenon of evaluation index values;

3) Through the normalisation of indicators, grey division of evaluation grade and contingency clustering, the grey comprehensive clustering of indicators is completed to avoid the phenomenon of jumping due to the evaluation index value. Then, the effective evaluation of monitoring accuracy of sports bracelet is realised according to the relative membership degree of evaluation index.

2 Design of precision evaluation method for sports bracelet monitoring

Iterative algorithm was used to process a large number of data generated in sports bracelet monitoring to avoid the impact of missing or abnormal data on evaluation results and evaluation time. Then, a fuzzy comprehensive evaluation model was established to reflect the prominent influence of different evaluation indexes and calculate the relative membership degree of evaluation indexes. Finally, grey clustering algorithm is used to optimise the fuzzy comprehensive evaluation model.

2.1 Sports bracelet monitoring data processing

In order to achieve an effective evaluation of the accuracy of sports bracelet monitoring, is essentially for sports bracelet, we evaluate the results of the monitoring data, because in the process of movement monitoring bracelet will produce a lot of quantity, and in the process of the actual monitoring data records, because of the influence of the communication terminal or surrounding environment factors, there will be a lack of data or data abnormal situation (Guo et al., 2019). In order to record complete and accurate monitoring results and provide a reliable data basis for monitoring accuracy evaluation, the monitoring data of sports bracelets were firstly processed. Through the application of iterative algorithm, the old values of variables can be recursively generated new values, which can improve the effect of data processing to a certain extent. The implementation steps of this method are as follows:

Assuming that the sports bracelet monitoring data set contains two interference points, p and q, and there is a Hamming distance between the two, expressed as $D(p,q)$, and the modal existence forms of the two interference points are respectively used as p_α and p_β indicate that the distribution set of data interference points $C=\{c_1,c_2,\ldots,c_n\}$ is obtained according to $D(p,q)$ and the modal form, where n represents the amount of data, for the initial clusters in the data set Make an estimate.

$$z(X_0)=\frac{z(x_{i0},x_{i1},\ldots,x_{iN})}{\Delta x_i} \tag{1}$$

In the formula, i represents the monitoring data sequence; z represents the initial cluster centre; Δx_i represents the monitoring data cluster centre; X_0 represents the estimated coefficient; N represents the number of iterations. In the initial clustering process, the data set containing interference points is assigned to a certain cluster centre through continuous iteration.

$$U^T=\sum_{i=1}^{n}\left|U_{t,i}-1\right| \tag{2}$$

In the formula, $U_{t,i}$ represents the state vector of the monitoring data. To obtain the monitoring data clustering centre matrix, the following constraints need to be met.

$$\begin{cases} v_{\max,d} & d \geq 1 \\ v_{\min,d} & d < 1 \end{cases} \tag{3}$$

In the formula, $v_{\max,d}$ represents the maximum value of data clustering space; $v_{\min,d}$ represents the minimum value of data clustering space.

Under the constraint conditions shown in formula (3), it is assumed that the segmentation category of the monitoring data set is.

$$Y_k = \left\{ y_1^{(k)}, y_2^{(k)}, \ldots, y_m^{(k)} \right\} \tag{4}$$

In the formula, $y_m^{(k)}$ represents the *m*-th value in the new cluster centre. By calculating the Euclidean distance to obtain the neighbouring points of the monitoring data clustering centre, there are:

$$D_{ik} = \frac{d_i - d_j^{\,2}}{x_{id}^{(k-1)} + x_{id}^{(k)} + x_{id}^{(k+1)}} \tag{5}$$

In the formula, d_i and d_j both represent data type attributes; $x_{id}^{(k-1)}$, $x_{id}^{(k)}$ and $x_{id}^{(k+1)}$ represent adjacent data points. Based on the above analysis, an objective function for clustering of sports bracelet monitoring data is established:

$$\eta_{ij} = \sqrt{\sum_{i=1}^{M} \sum_{j=1}^{N} \left[H_s(i,j) - H_g(i,j) \right]^2} \tag{6}$$

In the formula, $H_s(i,j)$ represents the attribute mixed data; $H_g(i,j)$ represents the homogeneous related data; M represents the average value of the iteration.

According to the above calculation process, when the average value of the data is equal to the average value of the iteration, the calculation formula for the cluster centre of the sports bracelet monitoring data is:

$$\Phi_{ac} = \Delta t \times \left(H_s - H_g \right) \tag{7}$$

The data processing process of sports bracelet monitoring based on iterative algorithm is summarised as follows:

1) Two interference points were obtained by dividing the monitoring data set of the Hand-ring of the Universiade;
2) Estimate the initial cluster of the data set and assign the data set where the interference point is located to a cluster centre;
3) Constraint conditions were established to obtain the clustering spatial range of monitoring data; if the constraints are not met, go to Step (1). If the constraints are met, continue to perform the following operations.

4) The adjacent points of the monitoring data cluster centre are obtained by calculating Euclidean distance D_{ik}, and the monitoring data processing results are obtained and represented by the data cluster centre.

To sum up, by processing sports bracelet data, it can effectively avoid the impact of data loss or abnormality on the quality of evaluation results and evaluation time.

2.2 Build the sports bracelet monitoring accuracy evaluation model based on grey comprehensive clustering algorithm

2.2.1 Fuzzy clustering of indicators

In the process of monitoring accuracy evaluation of the actual sports bracelet, the evaluation criteria involved include the median error, relative error, limit error and allowable error of the evaluation results. Some of the evaluation indicators will have outstanding influence. This kind of prominent influence mainly means that the index will affect the accuracy of the evaluation result (Rahman et al., 2019; Tonacci et al., 2019; Chae et al., 2021). Therefore, based on the processing results of sports bracelet monitoring data in Sub-section 2.1, a basic fuzzy comprehensive index relation is established to comprehensively reflect the prominent influence of different evaluation indicators. The expression of this relation is as follows:

$$N_i(t) = z_0 + \frac{x_i(t) \times x_j(t)}{N_{ij}^2} \tag{8}$$

In the formula, $x_i(t)$ represents the non-linear characteristics of the evaluation index; $x_j(t)$ represents the fuzziness of the evaluation index; N_{ij}^2 represents the relative membership degree of the evaluation index.

In general, when all the evaluation indicators of the sports bracelet monitoring accuracy evaluation object are consistent, the obtained evaluation results should also be consistent. However, in fact, the evaluation result is a bounded value. When the value of all evaluation indexes of one evaluation object is higher than that of another evaluation object, the evaluation index of the former is better than that of the latter, which will lead to the difference of evaluation results (Lin et al., 2019). At the same time, the increase of each evaluation index will lead to the increase of evaluation index value. This increase trend has the characteristics of continuity, and the increase trend is relatively stable without jumping.

Through the above analysis, the fuzzy evaluation matrix of relative membership degree is obtained in combination with formula (8), which can be expressed by formula (9).

$$N' = (z_1, z_2, \ldots, z_n) z_0 = \begin{bmatrix} z_{11} & z_{12} & z_{1n} \\ z_{21} & z_{22} & z_{2n} \\ z_{n1} & z_{n2} & z_{nm} \end{bmatrix} \tag{9}$$

Then, the composition operator in the fuzzy evaluation matrix can be expressed as:

$$Z_r = \sum_{i=1}^{N} RD^i \times D^{i2} \tag{10}$$

In the formula, RD^i represents the comprehensive evaluation vector; RD^i represents the weight vector of the evaluation index.

When there are obvious differences in the degree of outstanding influence of each evaluation index, that is, the degree of outstanding influence of some indexes is small, some indexes do not have outstanding influence and the degree of outstanding influence of some indexes is relatively large (Tan et al., 2020). Under the above conditions, when evaluating the monitoring accuracy of sports bracelets, if there are k differentiated evaluation indicators, a subset of evaluation factors is formed, which can be expressed by formula (11):

$$K = \{k_1, k_2, ..., k_m\} \tag{11}$$

According to formula (11), the evaluation factors in the evaluation factor subset are divided into multiple sets of different levels to obtain a comprehensive evaluation set. Assuming that there are g levels in the set, the evaluation set composed of g levels can be expressed as:

$$G = \{g_1, g_2, ..., g_k\} \tag{12}$$

Since different evaluation factors have a certain correlation, they will all have an impact on the evaluation results. Although the degree of influence is inconsistent, any evaluation factor cannot be ignored. Therefore, a correlation function is set:

$$S^k = \sum_{i=1}^{n} e^{X_{ik}^d} \tag{13}$$

In the formula, e represents the degree of correlation between indicators; $e^{X_{ik}^d}$ represents the weight coefficient of the evaluation index system, and the calculation formula is as follows:

$$Q^2 = A(t)\left[T(x) - T(y)\right] \tag{14}$$

In the formula, $A(t)$ represents the coordination coefficient between each index; $T(x)$ represents the index importance assignment; $T(y)$ represents the index variation coefficient.

Start rating for the first evaluation index in the evaluation set, and use this as a basis to determine the degree of association between the evaluation object and the elements of the evaluation set, and use Ψ_h to represent the evaluation result of the h-th evaluation index, so as to obtain the evaluation results of different indicators, form a fuzzy evaluation set, the specific expression is:

$$H_q = \{\Psi_{h1}(t), \Psi_{h2}(t), ..., \Psi_{hn}(t)\} \tag{15}$$

The weight of the evaluation index can reflect the difference between different evaluation indexes. The weighting value of the evaluation index is calculated by the excess weighting method. The calculation formula is as follows:

$$F(y) = \frac{e^{y} - e^{-y}}{e^{y} + e^{-y}} \tag{16}$$

Based on formula (16), a grey comprehensive clustering evaluation model is established to determine the evaluation index level and obtain the evaluation results of sports bracelet monitoring accuracy. The specific calculation formula is:

$$F_h^2 = E_{fh} - \left[E_h' + \left(x_d - x_d' \right) + \left(E_q' - 1 \right) \right] \tag{17}$$

In the formula, E_{fh} represents the efficacy function; E_h' represents the coordination degree function; x_d represents the parameter system; E' represents the comprehensive evaluation index system.

2.2.2 The monitoring accuracy of sports bracelet was evaluated based on grey comprehensive clustering algorithm

The evaluation model constructed above can be used to evaluate the monitoring accuracy of sports bracelet. However, the establishment of the evaluation model mentioned above is achieved to some extent by means of membership degree, but if there is no obvious difference in membership degree of evaluation indexes, the judgment effect of evaluation indexes will be affected (Siddharth et al., 2019; Zhao et al., 2019). Therefore, this paper uses grey comprehensive clustering algorithm to optimise the monitoring accuracy evaluation model of the sports bracelet. Grey comprehensive clustering is one of the grey techniques widely used in grey system theory, and its essence is a variable weight clustering method, which can judge the membership degree of different indicators through variable weight clustering, so as to avoid the problem of inaccurate evaluation results. The specific evaluation steps are as follows:

1) Assuming that there are α clustering objects, such clustering objects refer to monitoring data and β clustering indicators. The clustering indicators here refer to evaluation indicators. An observation value ∂ is set up, and its role is to correct the clustering index is classified, and the evaluation index is divided into Γ grey classes by this value (Sun et al., 2019) and the set composed of different grey classes is the grey cluster;
2) The grey classes are divided according to the actual evaluation requirements, and the whitening weight function of clustering index is obtained;
3) Calculate the clustering coefficient of the evaluation object s with respect to the v-th grey class;
4) The normalised clustering coefficients of each evaluation index are calculated respectively;

5) According to the normalised clustering coefficient obtained in step (4), the comprehensive clustering coefficient is divided into different clustering spaces. There are obvious differences in the membership of each evaluation index in different clustering spaces, so as to avoid the problem of inaccurate evaluation results;
6) End.

To sum up, the iterative algorithm is used to process a large number of data generated in the monitoring of sports bracelets, and a fuzzy comprehensive evaluation model is established based on the data processing results. Through the model, the prominent influence of different evaluation indexes is reflected, so as to calculate the relative membership degree of evaluation indexes. Finally, the fuzzy comprehensive evaluation model is optimised by grey comprehensive clustering algorithm to realise the evaluation of monitoring accuracy of sports bracelet.

3 Experiment and result analysis

In order to fully verify the effectiveness and application value of the sports bracelet monitoring accuracy evaluation method designed based on grey comprehensive clustering, a comparative experiment was conducted to compare the method with the traditional method, and the application effect of the method was obtained by analysing and comparing the results.

3.1 The overall scheme design of the experiment

1) The simulation platform used in the experiment is mainly composed of four modules, which are data processing and storage module, circuit simulation module, algorithm simulation operation module and actual operation module. The simulation platform passed the Lab Centre in the UK The company's embedded system simulation development software protues draws the experimental results of the traditional method and the method in this article.
2) *Experimental data*: In experiment data acquisition part, randomly selected 20 subjects, unified wearing Fit bit Flex 2 types of sports bracelets and monitor for a month-long campaign to them, will be produced during all the data and normalised processing, in binary format compression forming a comprehensive data set, as source of the experimental data.
3) *Comparison method*: method of Hao et al. (2019), method of Huang (2018) and method of Li et al. (2015) are used as the comparison method, and method of this paper is compared and analysed.

3.2 The experiment indicators

To verify the application prospect of the proposed method, its application performance is verified from the following aspects:

1) *Accuracy of monitoring accuracy evaluation results*: The higher the accuracy of evaluation results, the more reasonable the evaluation results of this method are for sports bracelets; otherwise, the evaluation results will have a negative impact on the application effect of sports bracelets.

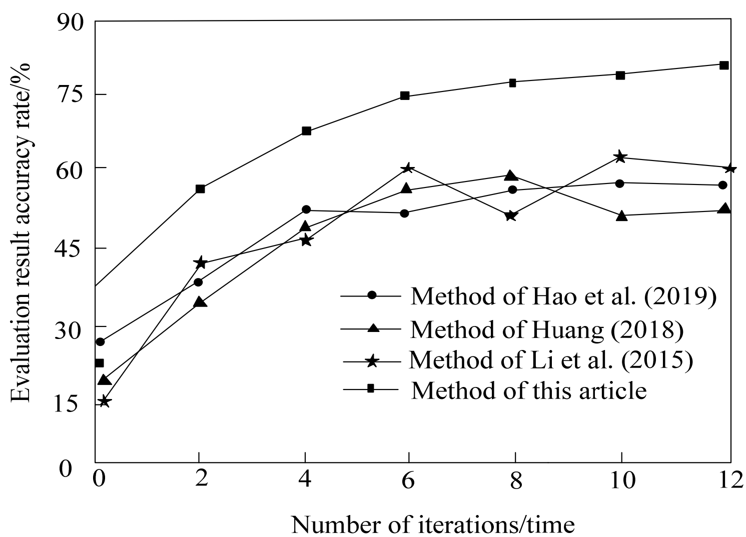
2) *The evaluation time of monitoring accuracy*: the evaluation time is the evaluation efficiency. The less the time, the higher the application value of the evaluation method.

3) *Effect of large-capacity data processing*: Since the sports bracelet will store a large amount of sports data and monitoring data in the application, it can realise the practicability of effective processing and direct reflection method for large-capacity data.

3.3 Results analysis

The accuracy of the monitoring accuracy evaluation results is used as an experimental indicator to compare the application effects of the method of this paper and the traditional methods. The results are shown in Figure 1.

Figure 1 Comparison of accuracy of monitoring accuracy evaluation results of different methods



By analysing the experimental results shown in Figure 1, it can be seen that the accuracy of evaluation results of method of this paper is always higher than that of traditional methods, and the trend of change has always been on the rise, while traditional methods have no obvious change rule, and there is a certain volatility. As can be seen from the random selection of experimental results, when the number of iterations is 6, the accuracy of evaluation results of method of Hao et al. (2019) is 52%, and that of method of Huang (2018) is 56%. The accuracy of evaluation results of method of Li et al. (2015) is 59%, while that of method of this paper is 74%. Further comparison of the highest accuracy of different methods shows that the highest value of method of this paper is 83%. The maximum values of method of Hao et al. (2019), method of Huang (2018) and method of Li et al. (2015) were 57%, 58% and 63%, respectively.

Based on the above comparison results, it can be seen that the evaluation results of method of this paper are more accurate, and the evaluation results can provide reliable data for sports bracelet wearers. The reason for this result is that the method in this paper reflects the prominent influence of different evaluation indexes by establishing comprehensive index relations before evaluation, so as to effectively avoid the impact of the accuracy of evaluation results due to the jump phenomenon of evaluation index values.

The monitoring accuracy evaluation time was taken as the experimental index, and the application effects of method of this paper and traditional methods were compared. The results are shown in Table 1.

Table 1 Comparison of monitoring accuracy evaluation time between different methods/s

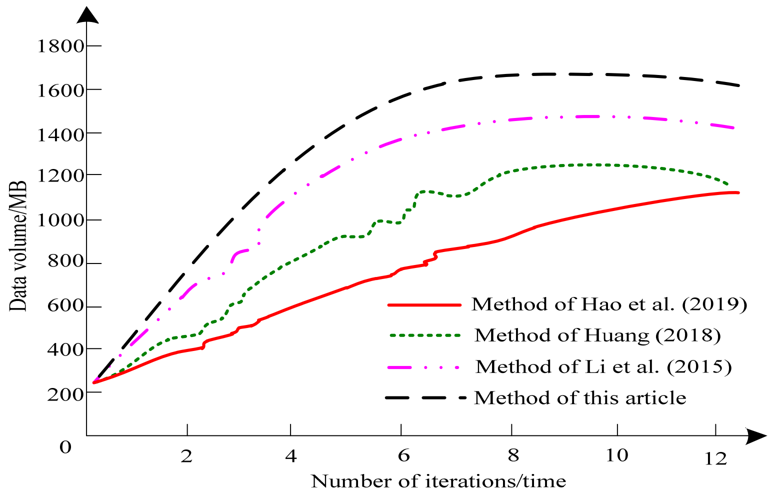
Number of iterations/times	*Method of this paper*	*Method of Hao et al. (2019)*	*Method of Huang (2018)*	*Method of Li et al. (2015)*
2	0.8	2.7	3.6	1.7
4	1.1	2.9	3.7	2.1
6	1.2	3.5	3.9	2.5
8	1.4	3.8	4.3	2.8
10	1.6	4.1	4.7	3.0
12	1.6	4.6	5.0	3.4

By analysing the data in Table 1, it can be seen that the variation rule of monitoring accuracy evaluation time of different methods is consistent, which increases with the increase of iteration number. However, by comparison, the evaluation time of method of this paper is lower, the lowest time is only 0.8 s, and the highest time is lower than that of traditional methods. Method of this paper can realise the evaluation of the monitoring accuracy of sports bracelets in the fastest time, and can provide timely information for users of sports bracelets. The reason for this result is that the method in this paper does not directly apply the original collected data to implement the evaluation, but uses the original data to recurse the new data, so as to avoid the problem of increasing the evaluation time caused by data missing or abnormal.

The processing effect of large-capacity data was taken as the experimental index, and the application effect of method of this paper and traditional methods was compared. The results are shown in Figure 2. Capacity refers to the amount of data that can be processed by different evaluation methods under the same conditions. The larger the amount of data is, the higher the application value of the method is.

Owing the large amount of monitoring data of sports bracelet, different methods can be used to effectively process these data, but there are differences in data processing capacity. According to Figure 2, the data processing capacity of method of this paper is significantly higher than that of traditional methods, and the amount of data it can effectively process is more than 1600 MB.

Figure 2 Comparison of the effect of different methods on large data processing



This result shows that method of this paper can process a large amount of data and is not easy to cause data loss. The reason for this result is that the method in this paper uses the original sports bracelet monitoring data to recurse the new data, so as to effectively avoid affecting the quality of evaluation results due to data missing or abnormal.

4 Conclusion

1) In view of the problems existing in traditional methods, such as low accuracy of monitoring accuracy evaluation results, long time of monitoring accuracy evaluation and poor processing effect of large volume data, this paper proposes a sports bracelet monitoring accuracy evaluation method based on grey comprehensive clustering. This method uses iterative algorithm to process a large number of data generated in sports bracelet monitoring, including sports data, sports energy consumption, body state, etc., to avoid the impact of missing or abnormal data on evaluation results and evaluation time. Then, the fuzzy comprehensive evaluation model is used to reflect the prominent influence of different evaluation indexes, so as to calculate the relative membership degree of evaluation indexes. Then, the grey comprehensive clustering algorithm is used to optimise the model constructed in the previous step, so as to realise the evaluation of the monitoring accuracy of the sports bracelet.

2) Analysis of the experimental results shows that the method of monitoring the accuracy evaluation results high accuracy was 83%, the evaluation time is low, the lowest takes only 0.8 s and able to deal effectively with the amount of data that reached more than 1600 MB, the experiment indexes are better than the traditional method, shows that the method can effectively promote sports bracelet monitoring accuracy evaluation effect.

3) In the next research stage, the application scope of this method will be expanded to apply it to more equipment monitoring accuracy evaluation.

References

Ash, G.I., Stults-Kolehmainen, M., Busa, M.A., Gregory, R. and Pitsiladis, Y.P. (2020) 'Establishing a global standard for wearable devices in sport and fitness: perspectives from the New England chapter of the American college of sports medicine members', *Current Sports Medicine Reports*, Vol. 19, No. 2, pp.45–49.

Bai, M.X., Zhai, Y.J., Liu, F., Wang, Y.N. and Luo, S.D. (2019) 'Stretchable graphene thin film enabled yarn sensors with tunable piezoresistivity for human motion monitoring', *Scientific Reports*, Vol. 9, No. 4, pp.186–124.

Chae, U.R., Kim, K., Choi, J., Dong, J.H. and Chung, M. (2021) 'Systematic usability evaluation on two harnesses for a wearable chairlessexoskeleton', *International Journal of Industrial Ergonomics*, Vol. 84, No. 8, pp.103–112.

Guo, J., Yang, L., Bie, R., Yu, J., Gao, Y., Shen, Y. and Kos, A. (2019) 'An XGBoost-based physical fitness evaluation model using advanced feature selection and Bayesian hyper-parameter optimization for wearable running monitoring', *Computer Networks*, Vol. 151, No. 4, pp.166–180.

Hao, Y.Y., Zhang, L., Ma, X.K. and Cao, Z.B. (2019) 'The validation study on wrist – wearable activity monitors for monitoring physical activity', *Journal of Shanghai University of Sport*, Vol. 43, No. 4, pp.73–83.

Huang, B. (2018) 'Effect evaluation model of index grading and quantification of physical health monitoring', *Bulletin of Science and Technology*, Vol. 34, No. 3, pp.271–274.

Li, Y.T., Zhang, F., Yang, C.H. and Yang, D.Y. (2015) 'Research on quality metric of wearable devices', *Electronic Product Reliability and Environmental Testing*, Vol. 33, No. 4, pp.22–24.

Lin, B.S., Jhang, R.J. and Lin, B.S. (2019) 'Wearable cardiopulmonary function evaluation system for six-minute walking test', *Sensors*, Vol. 19, No. 21, pp.46–56.

Rahman, N., Yamada, Y. and Nordin, M. (2019) 'Analysis on the effects of the human body on the performance of electro-textile antennas for wearable monitoring and tracking application', *Materials*, Vol. 12, No. 10.

Sam, A., Gb, B., Cf, B., Ip, C., Mf, D., Alp, C. and Ma, A. (2021) 'Measuring human physiological indices for thermal comfort assessment through wearable devices: a review', *Measurement*, Vol. 183, No. 3, pp.109–122.

Siddharth, Patel A.N., Jung, T.P. and Sejnowski, T.J. (2019) 'A wearable multi-modal bio-sensing system towards real-world applications', *IEEE Transactions on Biomedical Engineering*, Vol. 66, No. 4, pp.1137–1147.

Sun, L., Tao, T., Zheng, X., Bao, S. and Luo, Y. (2019) 'Combining density peaks clustering and gravitational search method to enhance data clustering', *Engineering Applications of Artificial Intelligence*, Vol. 85, No. 10, pp.865–873.

Tan, Q.K., Wei, T., Peng, W., Yu, Z. and Wu, C.R. (2020) 'Comprehensive evaluation model of wind farm site selection based on ideal matter element and grey clustering', *Journal of Cleaner Production*, Vol. 272, No. 9, pp.122–138.

Tonacci, A., Billeci, L., Burrai, E., Sansone, F. and Conte, R. (2019) 'Comparative evaluation of the autonomic response to cognitive and sensory stimulations through wearable sensors', *Sensors*, Vol. 19, No. 21.

Zhao, B., Ren, Y., Gao, D. and Xu, L. (2019) 'Performance ratio prediction of photovoltaic pumping system based on grey clustering and second curvelet neural network', *Energy*, Vol. 171, No. 4, pp.360–371.