Research on intelligent detection method of new energy vehicle power battery based on improved ViBe algorithm

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Abstract

BACKGROUND: Traditional foreground detection methods for new energy vehicles using the ViBe algorithm often suffer from ghosting effects, which can obscure the accurate detection of moving targets.
AIMS: This study enhances foreground detection accuracy by addressing ghosting issues in the ViBe algorithm and improving the battery pack state detection system for new energy vehicles.
METHOD: The method includes analyzing global light changes before foreground detection and updating the background model using the three-frame difference method. The system integrates hardware and software to process data with the ViBe algorithm, measuring voltage from twelve 18650-type lithium batteries.
RESULTS: The battery management system prototype exhibits an absolute measurement error within -1.2 mV compared to the high-precision multimeter. The system maintains measurement accuracy across varying temperatures, demonstrating effective environmental adaptability.
CONCLUSION: The enhanced system successfully reduces ghosting in foreground detection and provides reliable battery state monitoring. It is robust under extreme conditions, contributing to improved diagnostic capabilities and enhanced traffic safety.

Keywords Battery state detection, ViBe algorithm, new energy vehicles, ghosting effects, battery management system, safety monitoring

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1. Introduction

New energy cars are a result of today's environment, as the rapidly expanding traditional fuel of the car sector has harmed the natural environment and created an ever-widening energy gap. People's conception of low-carbon sustainable development is also becoming more and more prevalent [1]. The car manufacturing industry needs to move away from its reliance on fossil fuels and toward environmentally friendly, sustainable growth [2]. At the same time, encouraging the formation of new energy vehicles is an important way to create new economic growth points under the new industry in the post-financial crisis era [3]. New vitality vehicles' high energy utilization efficiency is a viable means to maintain the energy security of the country's automobile industry, and the growth in their utilization rate is an operational way to reduce automobile exhaust pollution of the environment [4]. The economic acceptability of new energy vehicles is low for several reasons, including the industry's tardiness in getting going, and issues with car battery replenishment and range [5]. The short range and lengthy charging times of the new energy vehicle battery packs, make using them most inconvenient for drivers [6]. Conversely, a limited number of new energy vehicle industries and a small number of high-priced new energy vehicle models were established as a result of the flaws in the new energy vehicle manufacturing industry and technical restrictions in the research and development process [7]. When comparing the cost of selling new energy vehicles to that of equivalent traditional petroleum vehicles, the cost of selling new energy [8]. Vehicles are significantly less expensive In addition to fostering the advancement of automotive manufacturing and maintenance technology and enhancing the creative skills of teaching and research staff in the field [9]. Research into novel electric vehicle battery monitoring and management techniques can also help revive the automotive repair industry and advance economic and social growth [10]. Literature [11] investigated an urban drive cycle to examine how much gasoline and electrical power an identical hybrid electric car used. The throttle filter was used to construct a forward-looking model. In comparison to traditional torque assist, a 1.2% fuel savings and 20.2% overall usage of energy are achieved through the application of an algorithm based on genes to optimized the ignition filter characteristics and the electrical motor workload percentage. Literature [12] The creation that utilized shared, autonomous, and environmentally friendly energy was the main of the developed power markets. Energy trading between vehicles (V2V) was a viable substitute, but that had drawbacks such as cyber attack and lack of confidence. Although conventional resolution procedures were not appropriate for real-time applications, blockchain technology had been suggested as a means of implementing safe and equitable energy sharing. In large-scale peer-to-peer energy exchange systems, the Block Alliance Consensus (BAC) mechanism was proposed to preserve the hash graph performance and fend off Sybil Attacks. The technique consists of an excellent reputation reward and a leadership selection system founded on encryption. Literature [13] While centralized renewable energy sources, such as wind and solar power, lower carbon emissions, their weather-dependent output makes uncertainty planning more difficult. Important methods for advanced Artificial Intelligence (AI) in decentralized hydroelectric system hazard prediction were introduced, and statistical machine learning (ML) was utilized to analyzed uncertain management in decentralized solar and wind power networks. Literature [14] proposed a manage the charging dynamics of Shared Autonomous Electric Vehicles (SAEVs), research suggested a sequence of vanishing threshold optimization strategies. By guaranteeing electricity grid stability, the models to optimized service quality. In addition, it looks at to be used the integration of sources of clean energy into the national grid provided administrators with a means of devising practical solutions for urban mobility and electrical. Literature [15] for battery lithium combust features, a target detection approach predicated on the enhanced algorithms was put forth. Multilayer the kernels, concentration modules with a multilayered interference, and the K-means algorithm were used by the model to increase detection accuracy without compromising detected speed. With an average F1 value of 90.00%, an overall evaluation index of 94.09%, and a real-time recognition of 42.09, the experimental findings meet the requirements for continuous monitoring and guaranteed security during the creation and manufacturing of electric automobiles. Literature [16] investigated the Copulas operation, the paper suggested a scenario production and reduction framework for load power under extreme weather conditions. The algorithm created shared distribution examples, fit the sample information used a non-parametric kernel density estimation technique, and chose the best copula function to serve as the joint probability distribution function. The statistics reveal that the generation situation was more realistic in capturing the real production and power consumption under challenging circumstances, setting a benchmark for managing and research of energy systems reliability [21][22][23].

In this paper, first of all, the traditional ViBe algorithm foreground target detection process will have the problem of ghosting, proposed based on ViBe and using a three-frame differential approach, the foreground finding of targets is improved. when the global light suddenly changes, through the mathematical morphology processing, eliminate the fine voids, smooth the boundary, and improved the final detection results. Then battery pack state detection system design, battery pack state detection hardware circuit mainly includes current acquisition circuit, temperature acquisition circuit, high and low voltage switch switching circuit, battery intelligent detection system software configuration program self-test completed to start the device and function verification, including device information, error information, CAN status, device parameters, etc., the function verification data information will be saved and displayed to the user interface synchronously Send to the system layer. Finally, the ViBe algorithm performance and system effectiveness are analyzed to verify that the algorithm in this paper reduces the appearance of irregular and fine objects in foreground detection, which makes the foreground target detection results more accurate, and also verifies that the detection system has better measurement accuracy in extreme temperature environments.

2. Improved foreground target detection based on ViBe and the three-frame difference method

2.1 Three-frame differential method

The target area detected by the inter-frame difference approach is far better than the particular intention area, and it is impossible to identify that overlapping region, which causes a decrease in detection accuracy [24][25]. An enhanced method predicated on the inter-frame contrast approach constitutes the three-frame differences technique. This algorithm first obtains three consecutive frames of the image sequence, binaries the difference between two frames, then does the “sum” operation on the two results to eliminate the overlapping area and finally performs morphological processing on the obtained results to obtain the final foreground target area. The specific process is shown in Fig. 1.

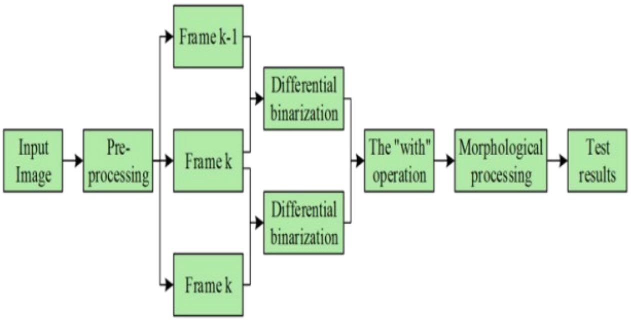

Figure 1. Three-frame differential detection process

The equation (1) is described as:

$$S_k(x,y) = T_k(x,y) \wedge T_{k+1}(x,y) \quad (1)$$

where $T_k(x,y)$ is the result of differential binarization of structure k and frame $k-1$, $T_{k+1}(x,y)$ is the result of differential binarization of $k+1$ and frame k, and $S_k(x,y)$ is the result of the "sum" operation of two differential binarization results $T_k(x,y)\ T_{k+1}(x,y)$.

2.2 ViBe algorithm

The fundamental idea driving ViBe, a pixels-based mobility detection technique, is to maintain the pixel values of the present frame with the corresponding domain in an experiment set that is set up for every pixel point within an image. During the detection process, the pixels of the detection frame are compared with all the sample values in the corresponding sample set, and if the pixel value of a point of the detection frame is more similar to the sample values in the sample set (greater than a threshold), the point is the former point of interest.

A sample set of size N is first created for each pixel, with the following equation. (2) expression:

$$M(x) = \{p_1, p_{2}, \ldots, p_N\} \quad (2)$$

Denote $p(x)$ as the pixels value at pixel x point: $S_R(p(x))$ is the area with x as the center R as the radius. If $S_R(p(x)) \cap \{p_1, p_2, \ldots p_N\}$ is regarded as the surroundings element if it exceeds the specified criterion.Fig.2. Shows The ViBe algorithm pixel classification and the pixels within the dashed region with x the center R as the pixels that fall below that threshold amount are called the radius of the circle.

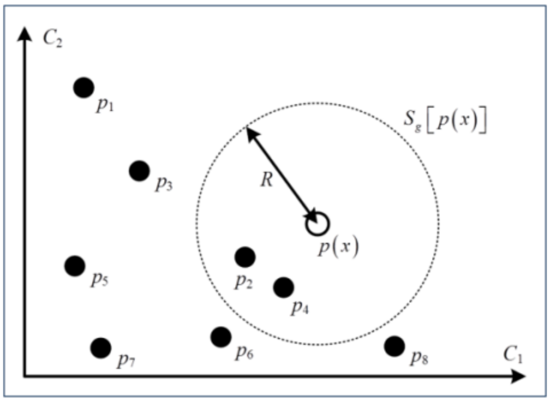

Figure 2. Pixel classification of the Euclidean space

While the ViBe technique just needs frames image for background model setup, the general background variation requires a video sequence. The ViBe approach builds an example set by selecting arbitrarily, for each pixel, the color values of its domain throughout the preparation phase. The Vibe algorithm uses a model update strategy usually there are two kinds. conservatively upgrade method and formerly demonstrate counts technique: the former point counting technique modifies the model by using a sampling of pixels that are identified as former points for consecutive times, whereas the conventional update strategies do not employ former points to update the underlying image [17-18]. The particular updates approach involves updating an initial value in an existing sample set of a detected foreground point at randomly whenever an individual pixel is identified. Also, there is a possibility of $1/\varphi$ randomly updating the background sample of a pixel in a domain, where φ is the time sampling factor. The ViBe algorithm initializes the background model with only one frame of images, while the background model is updated using a random update strategy. Although this background model initialization and updating strategy of ViBe can detect moving targets more accurately, there are also the following problems. In the detection, when the object in the background suddenly moves, the foreground will leave a "pseudo foreground" area in the target's original position, which is called a "ghost image". When the global illumination suddenly changes, due to the background model update is not timely in a certain period will be a lot of false detection. When the target movement is small for a long time, the ViBe algorithm will "update" part of the moving target to the background model, resulting in the background model "pollution".

2.3 Improved algorithm

Despite previous issues, this work enhances the ViBe algorithm, as shown in Fig. 3 Fig (a) is the schematic diagram of the detection process of the traditional ViBe algorithm, and Fig (b) is the schematic diagram of the method of recognition procedure described in this paper. This paper's technique evaluates global light alteration before object identification and updates the scenery model using the three-frame difference method's output.

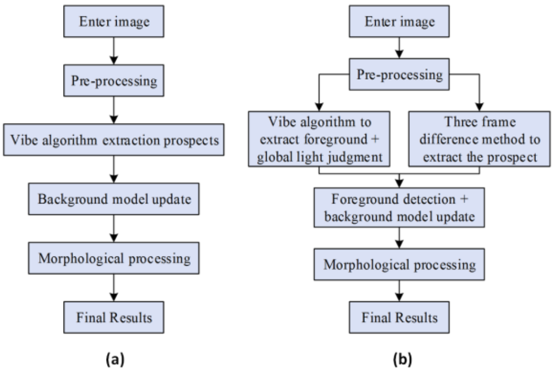

Figure 3. (a) Traditional Vibe algorithm and (b) proposed algorithm

2.3.1 Global light change judgment

When the global light changes suddenly, the ViBe algorithm will detect all the pixels with a large number of light changes as foreground, leading to false detection[26-28]. Therefore, it is necessary to perform light global change determination before detection to avoid such false detection. In this paper, the steps for determining the global change of light are as follows:

(1) When the foreground pixel area exceeds 74% of the total area, judgment is initiated and detection of foreground updates is suspended.

(2) The number of foreground spots of the result from the three-frame variation technique is continually calculated with the following 5 frames $N_1, N_2, \cdots, N_5$.

(3) When $T' > T$, it is judged as a global light change, and waits for 20 frames and the foreground is not detected by the three-frame difference method to initialize the ViBe algorithm background model, and when $T' \le T$, it is judged as normal foreground and continues detection. Where T' is defined as an equation (3-5).

$$N_{\max} = \max\left(N_1, N_2, \cdots, N_5\right) \quad (3)$$

$$N_{\min} = \min\left(N_1, N_2, \cdots, N_5\right) \quad (4)$$

$$T` = \left(N_{\max} - N_{\min}\right) / S \quad (5)$$

Where: S is the total number of pixels.

2.3.2 Background update strategy

The traditional ViBe algorithm uses a using a foreground point counted technique in conjunction with a cautious update strategy to modify a background framework, but the disadvantages of these two methods are also very obvious: Since a region is identified as incorrect forefront, it will always be treated as such because the traditional modify approach doesn't use foreground elements to update the background. The front point counting method updates the points that are detected as foreground for consecutive flights, and this strategy will also update the moving target as background if there is an object in the same area that keeps moving, resulting in a contaminated background model. In addition, the traditional ViBe algorithm's random update strategy tends to lead to slow background updates and ghosting.

2.3.3 Mathematical morphology processing

The expansion, erosion, opening, and closing operations are the basic operators of mathematical morphology, which can be combined or derived to form morphological algorithms to extract and measure the structure and morphology in images and also to perform some advanced image processing analysis. Generally, we set the image set a X nd the structure element B, and use B them to perform the relevant operations X. Here is how each of those basic procedures is carried out as follows:

(1) Expansion and corrosion

Expansion and corrosion are defined as shown in equations (6) and (7), respectively, and they are reciprocal operations:

$$X \oplus B = \bigcup_{b\in B}(X)_B = \{Y \mid Y = x + b, x \in B, b \in B\} \quad (6)$$

$$X \Theta B = \bigcap_{b\in B}(X)_B = \{Y \mid b \in B, (Y + b) \in B\} \quad (7)$$

During image processing, expansion can be used to fill small voids in smaller-than-structural component items. On the other hand, useless items shorter than building components are removed via weathering.

(2) Open and closed operations

Using corrosion and expansion operations, if the corrosion first and then expansion is called open operations, and vice versa for closed operations. The implementation of open and closed operations is shown in equations (8) and (9).

$$X \circ B = (X \Theta B) \oplus B \quad (8)$$

$$X \bullet B = (X \oplus B) \Theta B \quad (9)$$

These two operations are also called pairwise operations, in which the open operation can eliminate small objects, separate objects at fine points, and smooth larger objects. The closed operation can connect neighboring objects and smooth the boundary while its area changes are not obvious. In this paper, we perform morphological closed operations on the obtained foreground target detection results to eliminate small voids, smooth the boundaries, and improve the final detection results.

3. Battery pack status detection system

3.1 Hardware circuit for battery pack status detection

Vehicle initial data extraction, voltage acquisition circuit, current acquisition circuit, temperature acquisition circuit, high and low voltage switching circuit, and power management circuit based on improved ViBe are required to collect data such as voltage, current, and temperature, which require a reliable hardware platform to ensure reliable data by reducing hardware noise to improve signal-to-noise ratio [19].

3.1.1 Current acquisition circuit

The input and output power states of the battery are all calculated with current flow, and the ATS current calculation method can be used as part of the auxiliary capacity calculation. Fig.4. Shows that in current acquisition circuits, the current sensor is a Hall sensor, which collects bidirectional current, and the nominal sensor output voltage is 75mV/10A. The collected voltage is input to the positive side of the op-amp after the sampling resistor, and the voltage is input to the emitter following circuit after the negative feedback differential amplification circuit, and the final output is a stable current sampling value.

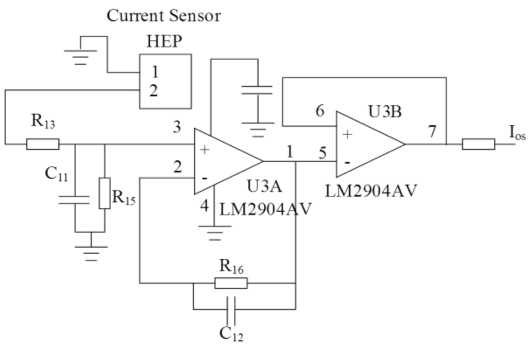

Figure 4. Current acquisition circuits

3.1.2 Temperature acquisition circuit

Battery temperature in the charging and discharging process will have a thermal imbalance problem occurs in the battery heating serious parts of the installation of Pt100 platinum resistance, platinum resistance into the full-bridge circuit can be converted into a voltage signal, and the full-bridge circuit output voltage can reduce the temperature drift of sampling and non-linear error. Battery temperature rises, the platinum resistance becomes larger, the output voltage increases, and the output voltage after 10 times the proportional differential amplifier circuit output temperature voltage Temp + signal, temperature sampling circuit as shown in Fig.5.

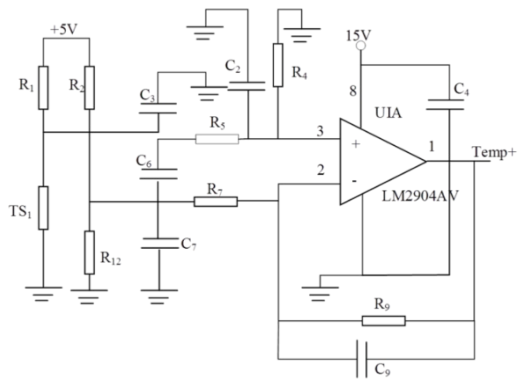

Figure 5. Temperature sampling circuit

3.1.3 High and low voltage switching circuit

The voltage of a single battery is 1.5V, and the module voltage is 150V after 100 batteries are connected in series, so the voltage needs to go through a high and low voltage switching circuit before it is transmitted to the hardware sampling circuit, and the high and low voltage switching circuit is shown in Fig. 6. When Q is high, Q1 and Q2 are on at the same time. Relays K2 and K3 are connected to the ground signal at the negative end and are connected to the power supply positive and negative at the same time.

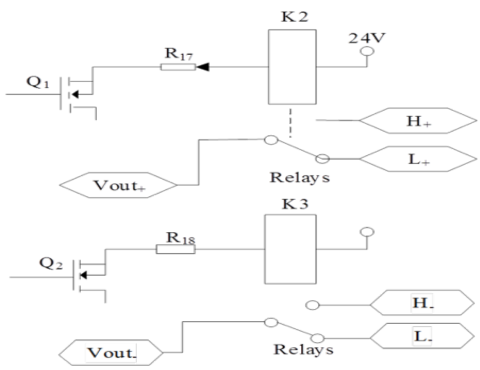

Figure 6. High and Low Voltage Switching Circuit

3.2 Battery intelligent detection system software configuration procedures

The overall software configuration program includes application layer and bottom layer development, application layer development includes user operation, data processing, logic judgment and other system layer applications, bottom layer development includes chip configuration, communication applications, interrupt timer, and other basic settings, this system integrates two types of settings configurations and description.

3.2.1 Overall system software design scheme

The overall design flow of the system software is shown in Fig.7. The operator turns on the device first, the system hardware as a whole establishes the power network, the system power supply is normal, and then starts to complete the initialization task of the system and the upper computer, after the self-test is completed, the device and function verification starts, including device information, error information, Controller Area Network (CAN) status, device parameters, etc. The data information of the function verification is saved and displayed to the user interface and sent to the system layer synchronously.

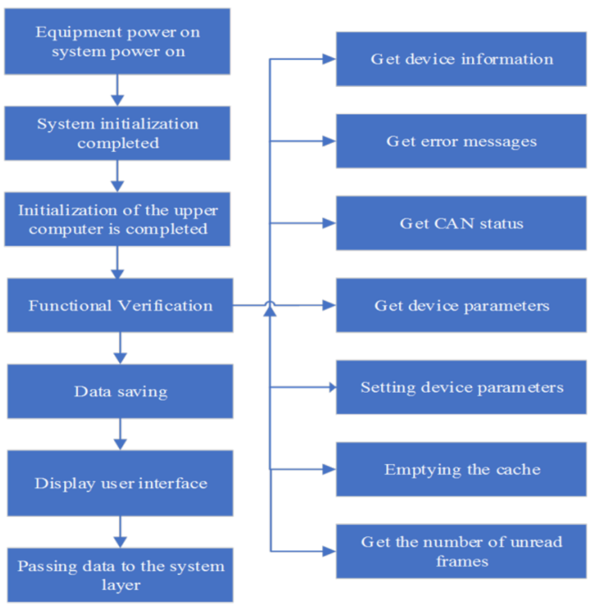

Figure 7. Overall system software design flow

3.2.2 Module multitasking configuration procedure

The application and data layer programs are common to each battery status detection system platform, but the underlying development program is based on the current hardware circuit, and the module multitasking program is an important part of the underlying program, the module multitasking program, as shown in Fig.8. Advanced RSIC Machine (ARM) is the core processor of the underlying hardware operation, and when it finishes the initial program loading it starts calling Digital Signal Processor (DSP), which is the core of data processing The ARM is the core processor of the underlying hardware operation, and when it finishes the initial program loading it starts to call the DSP, which is the core of the data processing, it can call various programs such as equalization task power module, data task, State of charge (SOC) task, etc., and when the data verification is completed In addition to transmitting to the consumer's machine of choice and saving data, it also simplifies the interrupted signal [20].

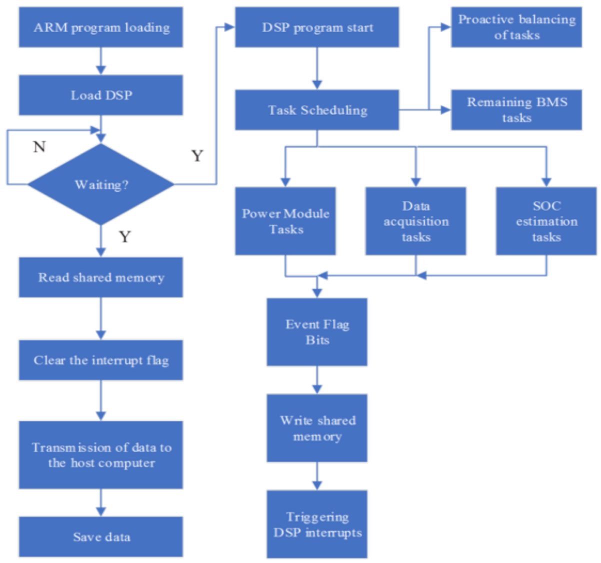

Figure 8. modular multitasking programs

4. Results and Analysis

4.1 Algorithm Performance Analysis

This validation of the improved algorithm was carried out in the Windows 7 operating system environment using $OpenCV3.2.0$ open source library and VS 2015 programming software. The experiments were carried out by taking the number of examples there are in a sample established $n = 20$, the threshold values of matching points $R = 20$ $\#min = 4$ $k = 10$, and the updated sampling rate was taken as 16, using $HighwayII$ video image sequences. Image pre-processing is an important part of motion target detection and tracking, grayscale image is removed from the color, the image becomes a single color, but does not affect the vehicle in any way, and the image details are not affected, and can improve the speed of subsequent processing; median filtered image removes the fine objects in the image, reducing the appearance of irregular fine objects in the foreground detection, making the detection results more accurate. Fig.9. Shows the variation of the number of ghost points considering the total amount of images for the aforementioned video sequence recognition, where the quantity of ghost points is indicated by the vertical location and the number of frames is indicated by the corresponding horizontal coordinate. The image illustrates how much faster the method employed in this study is in eliminating ghost shadows than both the ViBe algorithm and the combination of the Gaussian model, which can complete the elimination of ghost shadows in a short time, thus reducing false detections.

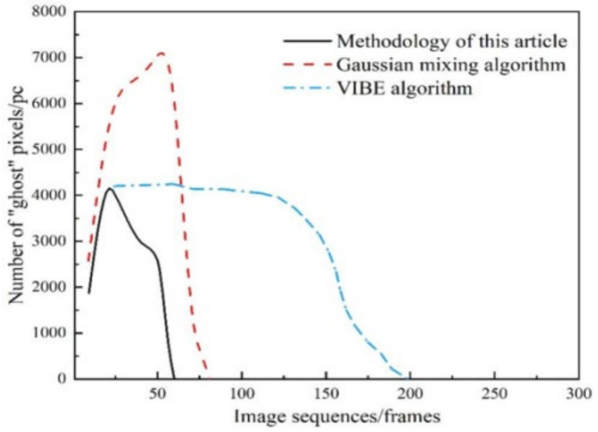

Figure 9. The Speed of Ghost Elimination

Finally, to illustrate the feasibility and superiority of the algorithm, this paper analyzes the above algorithm by calculating the system evaluation indexes: precision, recall, false detection rate, and comprehensive evaluation indexes with the following equation (10-13)

$$\text{Accuracy} = \frac{TP}{TP+FP} \quad (10)$$

$$\text{Recall rate} = \frac{FP}{TP+FN} \quad (11)$$

$$\text{False detection rate} = \frac{FP}{FP+TN} \quad (12)$$

$$\text{Overall Rating Indicators} = \frac{2\times\text{Accuracy}\times\text{Recall rate}}{\text{Accuracy}+\text{Recall rate}} \quad (13)$$

By testing the video $HighwayII$ and PETS2006 data with different detection algorithms respectively, the average of the multiple test results is taken as the final performance index of the algorithm. The statistical results are shown in Table 1, from which it can be concluded that the improved algorithm in this paper has improved in each performance index, and also outperforms the traditional Vibe algorithm. The ghosting issue with the original ViBe method during motion detection of targets is addressed by the enhanced Vibe background projection algorithm, which is shown to better suppress ghosting and, to some extent, increase the accuracy of foreground detection of new energy vehicles.

Table 1. Performance comparison of various algorithms

Algorithms	Accuracy	Recall rate	False detection rate	Comprehensive evaluation
Frame difference method	0.62	0.82	0.024	0.075
Hybrid Gaussian method	0.71	0.85	0.018	0.082
Traditional Vibe algorithm	0.82	0.92	0.011	0.85
Three-frame difference Vibe algorithm	0.85	0.93	0.011	0.91
The improved algorithm in this paper	0.89	0.93	0.009	0.093

4.2 System Testing

4.2.1 Voltage Measurement Accuracy Test

In this paper, 12 18650 type ternary lithium batteries are used as the measurement objects, and the single cell voltage is detected at room temperature with a six-and-a-half-digit high-precision digital multimeter and the electric vehicle battery management system designed in this paper respectively, Fig.10. Shows that Measurement accuracy of single voltage obtained. It is evident that the EV battery control method's absolute error of the individual cell voltage measurement values prototype relative to the measurement value of the high-precision millimeter is basically within -1.2mV, and the measurement accuracy is good, which will not affect the system’s judgment of the single cell overvoltage. Can work normally in extreme temperature environments and has good environmental adaptability.

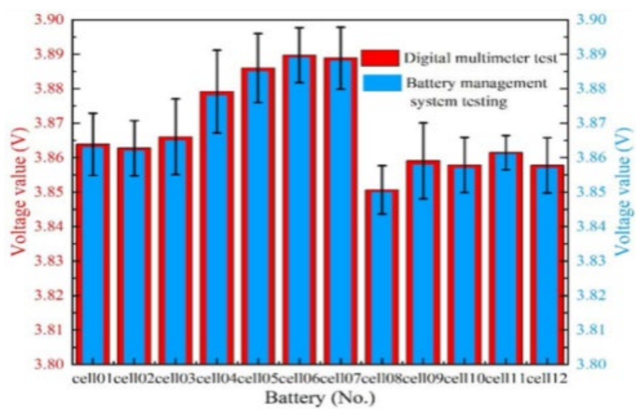

Figure 10. Measurement accuracy of single voltage

According to the design set by the battery system of eight groups of batteries consisting of sixty-four single cells, not only the analysis and management of every single cell but also the comparative analysis of the battery group is needed to find out the best single-cell and the most perfectly matched battery group, providing researchers with abundant data and experimental results. Fig.11. Shows the voltage variation of eight single cells of battery pack 1. It can be seen that the series 1, 3, 7, and 6 batteries are very high in the charging process, and the charging speed of battery 6 is slow, which needs more attention and calculation of its impact on the whole battery system during frequent charging and discharging. The results show that: the system can realize the monitoring and safety protection of battery operation, the abnormal processing and tracking of the near-end battery system can be realized through the remote host computer and cell phone mobile terminal, the diagnosis of fault information by the host computer is consistent with the result of intelligent processing of the battery management system, and the optimization of the consistency problem and the improvement of the balance management can be realized through the exchange of single batteries in the battery system. Through command transmission, remote control of the battery system can be realized.

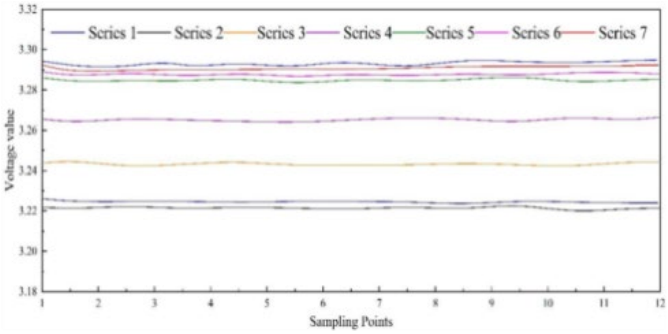

Figure 11. Voltage variations of eight individual cells of the battery pack

4.2.2 Temperature Measurement Accuracy Test

The temperature sensor probes were placed in the high-temperature test chamber with temperature settings of 40.0℃, 60.0℃, and 80.0℃, and the temperature measurement values of the prototype were recorded after the temperature of the test chamber was stabilized. Temperature measurement accuracy test results, as shown in Table 2. The absolute error of the temperature measurement value of the prototype under different temperatures relative to the set value of the high-temperature test chamber was within 1℃, and the measurement accuracy was good. Especially in the case of high temperature, the prototype has good measurement accuracy and will not affect the system's judgment of the battery over temperature.

Table 2. Temperature measurement accuracy test results

Temperature(℃)	T01	T02	T03	T04	T04	T06	T07	T08	T09	T10	T11	T12	T13
Set values							50						
Measured value	50	50	49	50	49	49	50	50	49	50	51	51	50
Absolute error	0	0	-1	0	-1	-1	0	0	-1	0	1	1	0
Set value							70						
Measured value	71	70	71	70	70	69	69	69	70	71	70	69	69
Absolute error	1	0	1	0	0	-1	-1	-1	0	1	0	-1	-1
Set value							85						
Measured value	86	85	86	85	85	84	84	84	85	86	85	84	84
Absolute error	1	0	1	0	0	-1	-1	-1	0	1	0	-1	-1

5. Conclusion

With the development of modern intelligence, this paper proposes the intelligent detection of new energy vehicle power batteries based on the improved ViBe algorithm. Firstly, ViBe algorithm foreground detection is used to extract the initial data of the new energy vehicle, and then the initial data is processed by the detection system to achieve intelligent battery detection, and the following conclusions can be drawn:
(1) The foreground target detection of new energy vehicles is the premise of achieving intelligent battery detection, and the performance analysis of the algorithm. Vibe algorithm and hybrid Gaussian model, the algorithm in this paper has a significant improvement on the speed of ghost shadow elimination, which can be completed in a short period to eliminate the ghost shadow, thus reducing false detection.
(2) The battery intelligent detection system is the practice to realize the battery intelligent detection, and the system carries out the measurement accuracy test and the temperature measurement accuracy test. The absolute error of the temperature measurement value of the prototype under different temperatures relative to the set value of the high-temperature test chamber is within ≧1℃, and the measurement accuracy is good. Especially in the case of high temperature, the prototype has good measurement accuracy and will not affect the system's judgment of battery over temperature.

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