Engineering Letters

Automatic Picking Method of P-wave Initial Time of Microseismic in Coal Mine

Hongyan Li, Jian Wu, Weifeng Wang

Abstract—**As national emphasis on coal mine safety intensifies, microseismic monitoring technology has become increasingly prevalent. This study presents an integrated algorithm that combines the Short-Term Average/Long-Term Average (STA/LTA) method with the Akaike Information Criterion (AIC) method to enhance the accuracy of P-wave onset detection in traditional microseismic monitoring. The novel algorithm employs an advanced STA/LTA approach to swiftly identify the approximate timing of the microseismic P-wave's initial arrival. Subsequently, it selects an effective time window encompassing the microseismic signal and applies the AIC method to precisely determine the P-wave's onset time. Experiments conducted on noisy microseismic signals from a coal mine demonstrate the algorithm's superior accuracy in initial time picking, even under the complex noise conditions typically encountered in coal mining environments.**

Index Terms—**AIC method, Coal mine safety,Initial time, Improving STA/LTA method, Microseismic signal**

I. INTRODUCTION

IN recent years, the scale of coal mining in China has continued to expand, leading to a concurrent rise in the risk of mining-related dynamic disasters. These disasters encompass a range of incident types, such as roof collapses, rock bursts, and water inrushes. According to the National Coal Mine Safety Administration, between 2000 and 2016, there were a total of 58 major and severe coal mine accidents in China, which resulted in 4,542 fatalities and 80 significant tragedies. As early as 2017, it was confirmed that 177 coal mines in China were at risk of rock bursts. In light of this dire situation, Chinese scholars have been actively engaged in research on mining safety, endeavoring to identify strategies and solutions to mitigate disaster-related casualties and enhance efficient rescue operations. They have discovered that microseismic signals are emitted during the fracturing process of coal and rock. These signals harbor crucial information regarding the timing, location, and extent of coal and rock damage.

Microseismic monitoring technology is extensively utilized for the early warning of dynamic disasters in coal mines. However, the complex underground environment, characterized by activities such as blasting and mining, generates substantial interference noise. This noise significantly reduces the signal-to-noise ratio, adversely affecting the precision of P-wave detection and source localization, which in turn impedes accurate disaster prediction. Consequently, enhancing the signal-to-noise ratio and accurately capturing microseismic signals has become a critical issue. Addressing this challenge is essential for improving the accuracy of source localization and predictive forecasting, thereby ensuring the safety of coal mining operations.

Numerous studies have been conducted by both domestic and international experts. Currently, the conventional methods for automatically detecting the initial arrival times of seismic phases in mine microseismic signals, which are inherently complex and transient non-stationary, can be categorized into four primary approaches: time-domain methods, frequency-domain methods, time-frequency domain methods, and hybrid methods[1]. Among these methods, time-frequency domain analysis encompasses several techniques, including the short-time Fourier transform (STFT), Wigner-Ville distribution, S-transform, wavelet transform, wavelet packet transform, Hilbert-Huang transform (HHT), and more recently, multi-method fusion denoising approaches[2-4]. These methods exhibit promising results in the feature analysis and noise reduction of non-stationary signals.

In the realm of time-domain analysis, Stevenson proposed the Short-Term Average/Long-Term Average (STA/LTA) method. This technique involves calculating the ratio of signal energy within a short time window to that within a long time window, thereby pinpointing the onset of the signal. While the STA/LTA method is noted for its simplicity and computational efficiency, its accuracy hinges on the judicious selection of time window sizes.

Expanding on the STA/LTA method, Yu Jianhua[5] conducted an in-depth analysis of four characteristic formulas, examining their effects on signal amplitude and frequency fluctuations. Yu innovatively introduced a weighting coefficient into the STA/LTA ratio, which substantially improved the method's noise resistance for signal onset detection. In response to the potential inaccuracy of static time window division in initial time picking, Zuo Guoping[6] proposed a rolling time window STA/LTA approach, significantly enhancing the precision and stability of the detection results. Ye Genxi[7], through experimental analysis, identified the pattern of STA/LTA value variation with time window length and proposed an adaptive initial picking method. This method was subsequently validated for its reliability. Despite the STA/LTA method's proven efficacy in detecting signal onset times, the selection of appropriate long and short time window durations and the trigger threshold remain critical factors influencing the accuracy of the picking process. Furthermore, in scenarios

Manuscript received July 3, 2024. revised December 5, 2024.

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with significant signal noise, the method faces challenges in accurately determining the signal's initial moment.

Beyond traditional time-domain analysis, a spectrum of frequency-domain and time-frequency-domain techniques has been embraced in the field[8]. Notably, the time-frequency domain energy ratio[9] and time-frequency analysis[10] have emerged as significant tools. Additionally, cutting-edge approaches including deep learning[11-12], transfer learning[13], and capsule networks[14] have achieved notable success in the precise identification of seismic wave onsets. Through rigorous statistical examination of waveform data, critical parameters such as skewness and kurtosis are harnessed to pinpoint the initial arrival of seismic signals. Collectively termed PAI-S/K[15], these statistical techniques have proven their mettle in providing initial arrival times with a high degree of precision.The Akaike Information Criterion (AIC) stands out as an efficient and precise tool for initial time picking. Its computational speed, coupled with the reliability of its results, has led to its widespread adoption across various applications.

Furthermore, the integration of the aforementioned methods has facilitated the development of innovative approaches for initial time picking. These novel techniques have been extensively applied in the field, yielding significant outcomes. For example, Zhang Huanlan[16] introduced a two-step automatic method for determining the initial time of microseismic events, utilizing the time window energy ratio and the Akaike Information Criterion(AIC); Tian Youping and Zhao Aihua[17] developed an integrated approach termed ‘Wavelet Packet-Peakness AIC’, which combines wavelet packet transform with the AIC; Jia Ruizheng[18] proposed an automatic picking method for seismic phase initial times, integrating the Hilbert-Huang Transform (HHT) with the AIC; Zhu Mengbo[19] enhanced the initial time picking process by combining the STA/LTA criterion with the Maximum Frequency Variation (MFV) criterion, resulting in an improved method named PAI-k-MFV. The essence of these comprehensive picking methods is their synergistic application of diverse techniques for the detection of microseismic wave initial times, effectively harnessing the strengths of each approach while compensating for their individual weaknesses.

This article provides an in-depth exploration of the core mechanisms underlying the STA/LTA and AIC methods, meticulously assessing their respective limitations and shortcomings. To surpass these limitations, the paper introduces an innovative strategy that integrates an enhanced STA/LTA approach with the AIC, culminating in a novel method for initial time picking. This integrated method preserves the adaptability of the STA/LTA while also leveraging the computational efficiency of the AIC. To substantiate the efficacy of this new method, extensive verification experiments were conducted using both simulated and field-collected data, demonstrating the method's superior performance in accurately picking the initial times of microseismic signals. The results of these experiments were further analyzed to identify areas for potential improvement, paving the way for future research to refine these techniques even further. The integration of these methods also opens new avenues for the development of more sophisticated seismic signal processing tools, which could have profound implications for the safety and efficiency of mining operations.

II. ANALYSIS OF AUTOMATIC PICKING METHOD OF MICROSEISMIC P-WAVE

A. STA/LTA Method

The STA/LTA method serves as a robust technique for identifying seismic events and pinpointing the initial times of seismic phases, functioning akin to a signal-to-noise (S/N) ratio measurement. Its core principle involves calculating the ratio of the short-term average to the long-term average within a time series dataset. Owing to its simplicity, minimal computational requirements, and the capacity for real-time processing, the STA/LTA method has been extensively utilized in the identification of seismic phases within natural earthquake signals. As microseismic monitoring technology continues to evolve, the STA/LTA method has captured the interest of experts and scholars, who have successfully adapted it for the analysis of microseismic signals, thereby highlighting its distinctive utility.

The underlying principle of this method entails determining the onset time of P-waves by assessing the disparities in amplitude, energy, and other characteristic metrics between microseismic events and noise signals. Throughout the computational process, the short time window's average value is highly responsive to abrupt changes in the amplitude of the time series, whereas the long time window's average value captures the characteristics of the underlying noise. The calculation formula is as follows:

$$STA(t)=\frac{1}{s}\sum_{i=t-s}^{t}CF(t) \tag{1}$$

$$LTA(t)=\frac{1}{l}\sum_{i=t-l}^{t}CF(t) \tag{2}$$

$$\frac{STA(t)}{LTA(t)}\geq\delta \tag{3}$$

In the formula, t is the sampling time of the signal; s is the length of the segment time window; l is the length of the long window; δ indicates the set trigger threshold. $CF(t)$ is the characteristic formula value of the signal at time t.

In the STA/LTA method, key parameters—including time window length, trigger threshold, and the characteristic formula—play pivotal roles in determining the precision of initial time picking. The selection of an appropriate short-time window length is essential to the STA/LTA approach. The average value of the characteristic formula within the short-time window is indicative of the signal's amplitude fluctuations, thus the choice of short-time window length directly influences the method's sensitivity to these fluctuations. A shorter window length enhances sensitivity to signal changes, whereas a longer window length exhibits reduced responsiveness to such changes. Consequently, the optimal short-time window length should be chosen based on the specific characteristics of the signal under analysis. Typically, the short-time window length should be 2-3 times the signal's primary period, while the long-time window length should span the noise period, approximately 5-10 times the length of the short-time window. It is important to note that an excessively long window may diminish the efficiency of initial time picking and increase computational load.Therefore, the determination of the long window length requires careful consideration to prevent any adverse impact on the method's efficiency. By judiciously selecting both the short and long window lengths, the method can more precisely capture signal fluctuations, thereby enhancing its accuracy and stability. Consequently, when employing the STA/LTA method, it is crucial to tailor the short-time window length to the specific context to ensure more reliable analytical outcomes.

Utilizing microseismic records from a specific mine in Yulin, we applied STA/LTA processing with varying lengths of short-time windows—specifically, 20, 50, and 80 sampling points—while maintaining a fixed length for the long-time window at 200 sampling points. The trigger threshold was established at 1.2. The outcomes of this processing are depicted in Figure 1 to 3. It was observed that a shorter short-time window yields a higher STA/LTA ratio, which is more likely to exceed the threshold and thus facilitates the accurate picking of the signal's initial time. Conversely, as the short-time window lengthens with the long-time window length held constant, the STA/LTA ratio diminishes, potentially falling below the trigger threshold and resulting in a failure to successfully identify the initial time. This underscores the significant influence that the selection of time window lengths exerts on the trigger threshold, highlighting the necessity for a comprehensive consideration of these parameters in light of the specific conditions at hand.

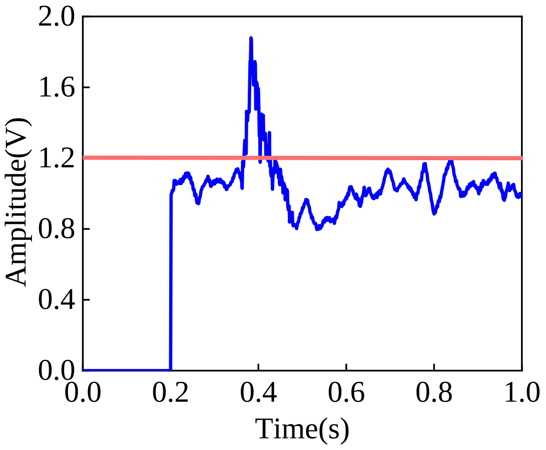


Fig. 1. STA/LTA value for Short window length 20

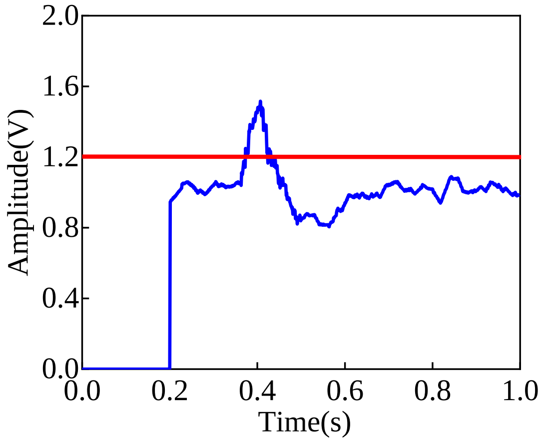


Fig. 2. STA/LTA value for Short window length 50

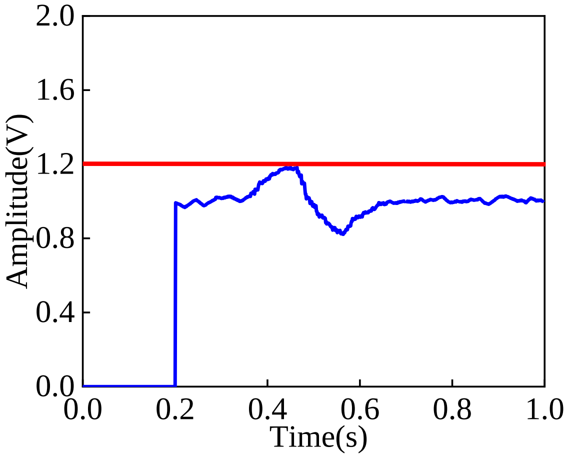


Fig. 3. STA/LTA value for Short window length 80

Characteristic formulas are instrumental in capturing the amplitude and frequency dynamics of microseismic signals, which in turn influence the sensitivity of the signal picking process. Below are some widely utilized characteristic formulas[20].

$$CF_1 = |X(i)| \tag{4}$$

$$CF_2 = X(i)^2 \tag{5}$$

$$CF_3 = X(i)^2 - X(i-1)X(i+1) \tag{6}$$

In the formula, i is the serial number of the signal sampling point; $X(i)$ is the amplitude of the signal at the i point; $X(i-1)$ is the amplitude of the signal at the $i-1$ point; $X(i+1)$ is the amplitude of the signal at the $i+1$ point.

The accurate extraction of the initial arrival wave is contingent upon the judicious selection of a trigger threshold. This selection must take into account not only the signal-to-noise ratio (SNR) of the signal but also the lengths of the time windows employed. An inappropriately chosen trigger threshold can result in erroneous identification of the initial time. Setting the threshold too high may cause the method to overlook microseismic signals, whereas setting it too low risks classifying noise as signals. Consequently, determining the optimal trigger threshold, in accordance with the signal's SNR and the duration of the time windows, is essential for precise initial time extraction using the STA/LTA method. Properly adjusting the trigger threshold is crucial for the accurate detection of microseismic signals, thereby enhancing the precision and reliability of the data processing.

B. AIC Method

The Akaike Information Criterion (AIC), developed by the distinguished Japanese statistician Hirotugu Akaike, is a cornerstone in the field of model selection and assessment. This criterion is highly valued for its capacity to quantify the goodness of fit of a statistical model relative to a given dataset, providing a balanced measure that considers both the complexity of the model and its explanatory power over the data's variability.In the specialized domain of microseismology, which is dedicated to the study of small-scale seismic activities, the AIC is indispensable. It assists researchers in precisely determining the initial arrival times of seismic phases, a task essential for comprehending the dynamics of seismic events and for analyzing the Earth's interior.For microseismic signals with a specified number of sampling points, the AIC calculation is performed as follows:

$$AIC(t) = t \cdot \lg\{\mathrm{var}(x[1,t])\} + (N-t-1) \cdot \lg\{\mathrm{var}(x[t+1,N])\} \tag{7}$$

In the formula,var is the variance of the data series.

In microseismic recordings, each microseismic event is typically characterized by a local minimum within the AIC calculation. By meticulously analyzing the time points associated with these local minima, the onset times of microseismic events can be identified. However, it is crucial to recognize that not all local minimum AIC values reliably indicate the initial times of microseismic events, as illustrated in Figure 5.

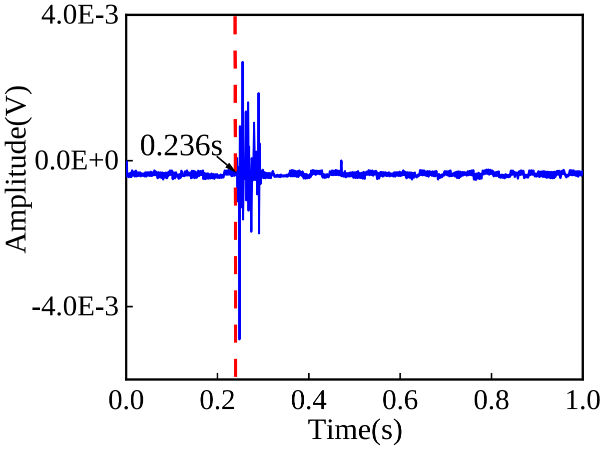


Fig.4. Manual picking of microseismic signals

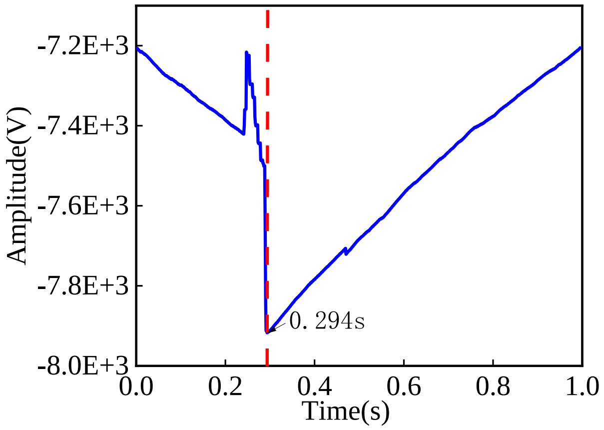


Fig.5. AIC method for full-time window picking

III. IMPROVED STA/LTA METHOD COMBINED WITH AIC METHOD FOR INITIAL PICKUP

A. *Improved STA/LTA Method*

The STA/LTA method is a prevalent technique for identifying the initial arrival times of microseismic signals. However, achieving high accuracy with this method necessitates careful calibration of several parameters. Paramount among these are the selection of appropriate characteristic formulas, the determination of the short and long time window lengths, and the setting of an appropriate trigger threshold. The selection of the trigger threshold must be informed by the signal-to-noise ratio (SNR) and may require fine-tuning in relation to the defined time window lengths. The precision of the initial time determination is significantly influenced by these parameters.

Although the three commonly utilized feature formulas facilitate automatic extraction, they are limited in their ability to reflect only the amplitude changes of the P-wave initial time, failing to capture frequency variations. While characteristic formulas can account for both amplitude and frequency changes, the varying signal-to-noise ratios (SNR) and energy levels of collected signals may introduce errors when the same formula is applied across different datasets. To address these limitations, this study augments the traditional STA/LTA method by introducing a weighting factor K and proposes a novel characteristic formula. The specific formulation is presented as follows:

$$K=\sum_{i=1}^{len}\left|X(i)\right|/\sum_{i=1}^{len}\left|X^{'}(i)\right| \tag{8}$$

In the formula, len is the number of signal sequences.

When constructing the characteristic formula, it is necessary to consider the frequency and amplitude variation characteristics of microseismic signals, and consider the weight factor to obtain the construction characteristic formulas:

$$CF=X(i+1)^{2}+K(X(i+1)-X(i))^{2} \tag{9}$$

In the aforementioned formula, components that capture the variations in signal amplitude are intricately combined with those that reflect changes in signal frequency. This synthesis results in a characteristic formula that encapsulates a wealth of information, offering a comprehensive depiction of the signal's amplitude and frequency characteristics. By calculating the STA/LTA ratio using this enriched characteristic formula, the necessity for manually setting a trigger threshold is obviated. The initial arrival time of the P-wave is ascertained by identifying the peak in the STA/LTA values. This methodology, which leverages both the characteristic formula and the STA/LTA ratio, significantly augments the precision of the initial time picking process.

B. *Improved STA/LTA Method And AIC Method Combined Initial Pick Method*

In this study, we introduce an innovative approach for the determination of seismic signal initial times by integrating an enhanced STA/LTA method with the AIC method. Initially, the refined STA/LTA method is employed to pinpoint the approximate onset of the P-wave within microseismic signals. Following this, the signal is extended by one-tenth of its length both anteriorly and posteriorly from this reference point to define the time window for the AIC method to precisely determine the initial time. The detailed procedure is delineated as follows:

1) Input the signal to be analyzed;

2) Select the long and short window length of STA/LTA method;

3) Calculate the STA/LTA value of the signal and identify the global maximum, denoted as i_1, on the STA/LTA curve as the approximate reference point for the initial time of the seismic event.

4) The AIC time window length, denoted as L,is determined by setting $L=i_1\pm l$,where i_1 is the index of the global maximum on the STA/LTA curve, and l is a value derived from the full signal length, specifically one-tenth of the total duration of the time window under analysis.

5) Compute the AIC value for the signal within the time window L ,and identify the minimum point i_2 as the approximate pick of the signal's first arrival time.

By integrating the STA/LTA method with the AIC method, we harness the complementary strengths of these techniques, offsetting their individual limitations and reducing the susceptibility to significant errors due to suboptimal parameter configuration. This integrated approach, with its enhanced STA/LTA component, effectively counteracts the AIC method's vulnerability to erroneous initial time picks, thereby enhancing the accuracy of microseismic signal analysis.

IV. EXPERIMENT AND ANALYSIS

A. Simulation Experiment Analysis of the Improved STA/LTA Method Combined with AIC Method for Initial Picking

To validate the effectiveness of our proposed initial pick method for microseismic events, we utilized a damped sinusoidal signal as a proxy for the event. This signal, which lasted for 1.5 seconds with the vibration commencing at the 0.6-second mark, was designed to simulate the characteristics of a real microseismic event. To add a layer of complexity and realism to our test, we incorporated 5 dB of ambient noise into the signal, reflecting the environmental noise that could interfere with signal detection in actual field conditions.

The resulting waveform, along with the manual picking results, is illustrated in Figure 7. This figure is pivotal as it visually represents the signal's behavior and the accuracy of our initial pick method amidst the introduced noise. It serves as a testament to the method's potential for precise event detection, even in the presence of disruptive background noise.

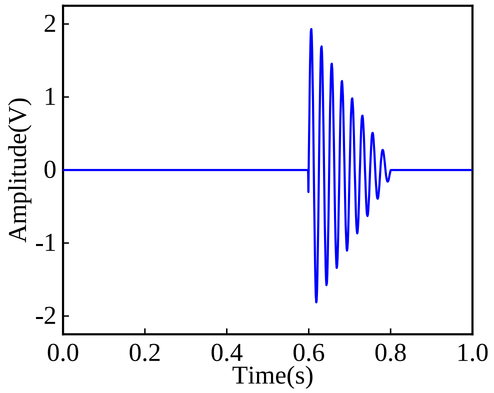


Fig.6 noiseless attenuation sine wave

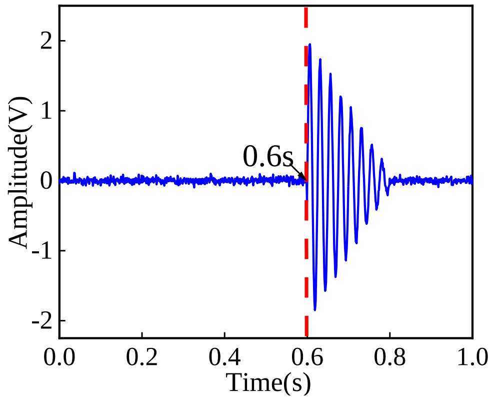


Fig.7 Attenuation sine wave with noise

When employing the STA/LTA method for initial time picking, the magnitude of the trigger threshold significantly influences the accuracy of the pick. An excessively high threshold may result in a failure to correctly identify the initial time. To address this issue, this study introduces a novel characteristic formula, redefining the criterion for the initial time as the global maximum of the STA/LTA value. We apply the enhanced STA/LTA method to the signal depicted in Figure 7. As illustrated in Figure 8, the maximum STA/LTA value occurs at 0.6094 seconds, which closely approximates the manually picked time, thereby validating the effectiveness of our method.

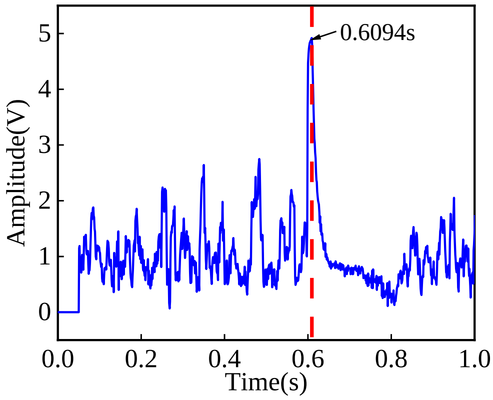


Fig. 8 Improve STA/LTA method initial time picking

During the identification of the P-wave's initial arrival within a full-time window using the AIC method, the minimum point does not always coincide with the actual initial time, as depicted in Figure 9. In such instances, the determined initial time of 0.7965 seconds significantly deviates from the manually picked time of 0.6 seconds, suggesting an erroneous pick. However, the accuracy of the AIC method can be markedly enhanced by constraining the time window length. In practical applications, the precise location of the initial time is often unknown, precluding the selection of an optimal time window limit. To circumvent this, we introduce an improved STA/LTA method to approximate the signal's initial time. Subsequently, we define the AIC method's time window by shifting the determined point forward and backward by one-tenth the length of the full-time window. The outcomes, presented in Figure 10, indicate an initial time of 0.5984 seconds, which differs from the actual initial time by merely 0.0016 seconds, thereby enhancing the precision of the picking process.

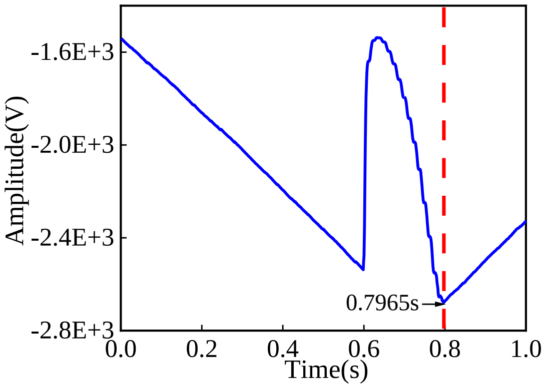


Fig. 9 AIC method Full-time window pickup

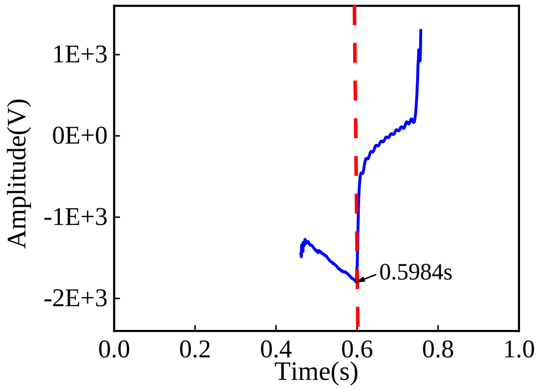


Fig. 10 the method of initially pick up in this paper

B. Experiment of Initial Arrival of Microseismic Signals in Coal Mine Environment

In evaluating the effectiveness of our refined method for microseismic signal analysis, we focused on a specific signal obtained from a coal mine in Yulin, Shaanxi Province, which lasted for 1 second. This signal served as a test case for our study. The initial arrival time of the P-wave, as determined manually, was marked at 0.367 seconds and is presented in Figure 11. This manual pick served as the benchmark for comparing the accuracy of automated methods.

The conventional STA/LTA method's automated detection of the P-wave was found at 0.409 seconds, which deviates from the manual pick by an error of 0.042 seconds, as depicted in Figure 12. This discrepancy highlights the room for improvement in automated picking techniques.

Our improved STA/LTA method, as detailed in this paper, achieved an automated P-wave pick at 0.405 seconds, resulting in a manual picking error of 0.038 seconds. This result is displayed in Figure 13 and represents a modest enhancement in accuracy over the traditional approach.

Most notably, the synergistic application of the improved STA/LTA method with the AIC method excelled in accuracy, identifying the P-wave's onset at 0.363 seconds. This result introduces a minimal error of merely 0.004 seconds when juxtaposed with the manual picking, as demonstrated in Figure 14. The comprehensive error analysis confirms that the hybrid approach of our enhanced STA/LTA and AIC methods not only reduces the initial time picking error but also outperforms the other automated methods discussed, offering a more precise and reliable tool for microseismic signal analysis.

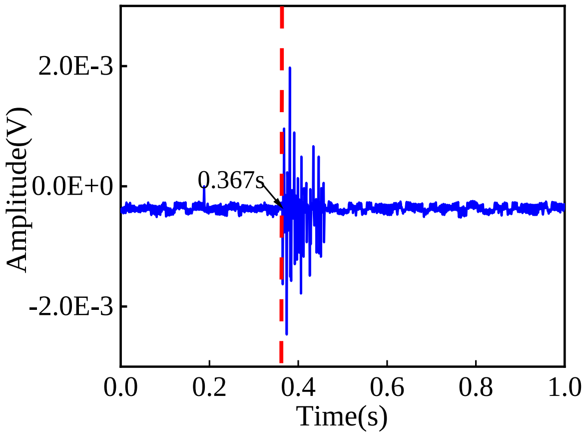


Fig. 11 The initial arrival time of the artificially picked microseismic signal

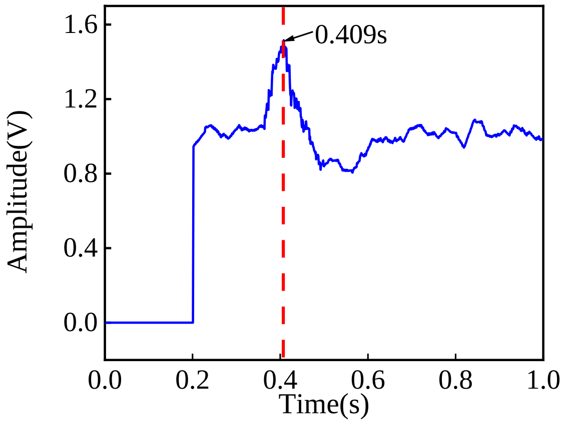


Fig. 12 Traditional STA/LTA microseismic signal pick-up time

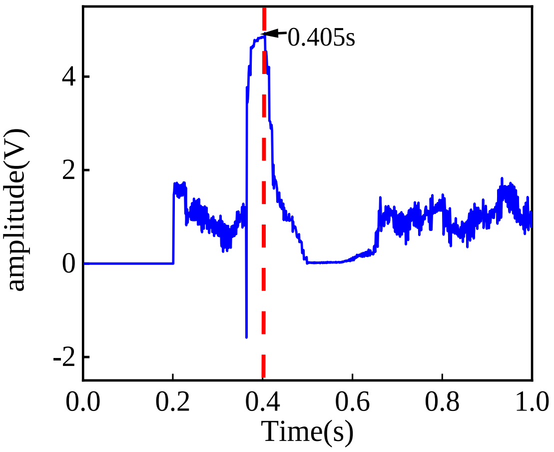


Fig. 13 Improved STA/LTA microseismic signal pickup time

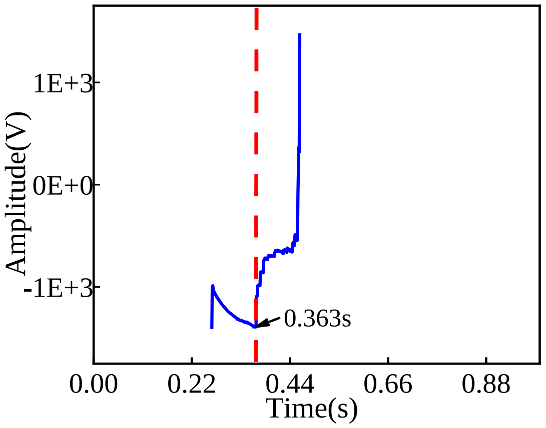
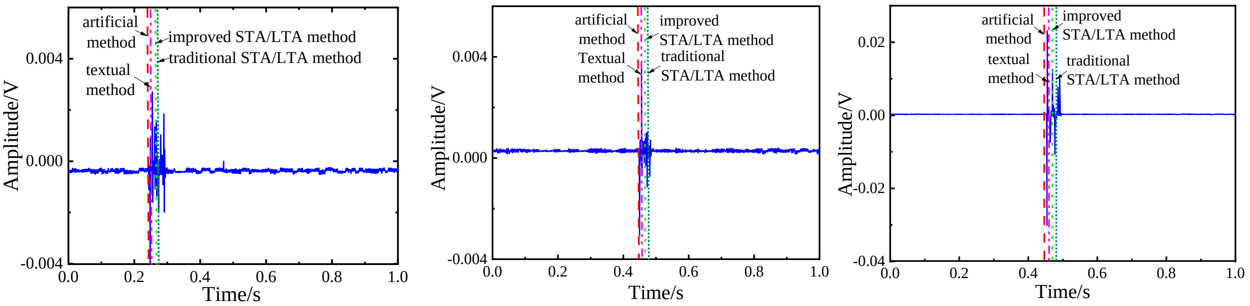


Fig. 14 The initial pick time of microseismic signals improved in this paper

To further substantiate the feasibility and precision of the hybrid picking method introduced in this study, we selected three microseismic signals, each 1 second in duration, from a coal mine for P-wave initial time picking using manual picking, the traditional STA/LTA method, the improved STA/LTA method, and the textual method presented herein. The results are summarized in Table 1 and Figure 15. The discrepancies between the traditional STA/LTA method and artificial picking times were 0.048 seconds, 0.042 seconds, and 0.048 seconds, respectively. The improved STA/LTA method exhibited differences of 0.020 seconds, 0.021 seconds, and 0.023 seconds, respectively. The combined method demonstrated the smallest deviations from manual picking, with differences of 0.001 seconds, 0.004 seconds, and 0.005 seconds, respectively. Collectively, these findings indicate that the textual method outlined in this paper achieves the highest accuracy in P-wave initial time picking.

TABLE I
THREE GROUPS OF SIGNALS ARE PICKED UP BY DIFFERENT METHOD

Picking method	signal 1	signal 2	signal 3
artificial method	0.236s	0.441s	0.446s
traditional STA/LTA method	0.284s	0.483s	0.494s
improved STA/LTA method	0.256s	0.462s	0.469s
textual method	0.237s	0.445s	0.451s



(a)signal 1 (b)signal 2 (c)signal 3

Fig. 15 Three groups of signals are picked up by different method

Additionally, to evaluate the computational efficiency of the method proposed in this study, we compared the computation times for processing two microseismic sign of identical length under identical computational conditions on the same hardware. The proposed method, the improved STA/LTA method, and the traditional STA/LTA method required 45ms, 32ms, and 29ms, respectively, for the first signal, and 46ms, 32ms, and 30ms, respectively, for the second signal. The results indicate that the computation time of the proposed method is marginally longer by 13 ms compared to the two STA/LTA methods. Despite this slight increase, the real-time performance of the proposed method remains satisfactory and within an acceptable range for practical applications.

C. Experiment of Initial Arrival of Microseismic Signals in Coal Mine Noise Environment

In the complex underground coal mine environment, the microseismic signals collected by the microseismic monitoring system are heavily interfered with by noise, making the first arrival points of the microseismic signals indistinct. This allows for the testing of the reliability of this method in noisy environments.

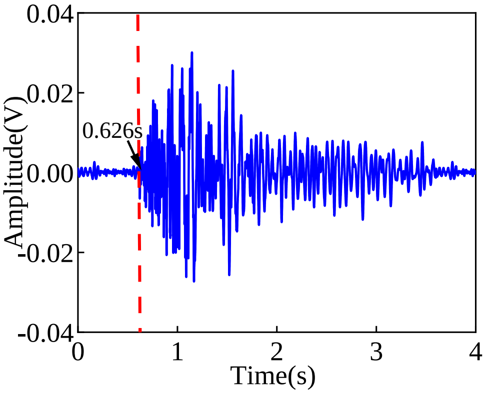


Fig. 16 The initial arrival time of the artificially picked microseismic signal

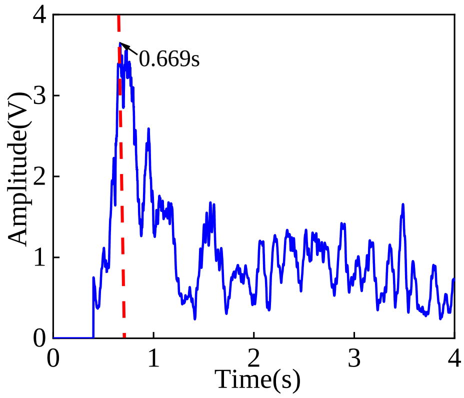


Fig. 17 Improved STA/LTA method microseismic signal pickup time

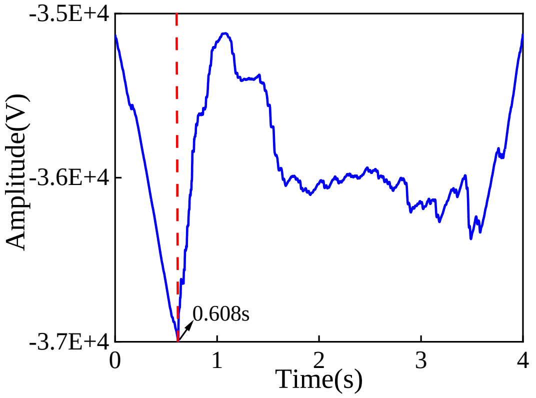


Fig. 18 AIC method microseismic signal pickup time

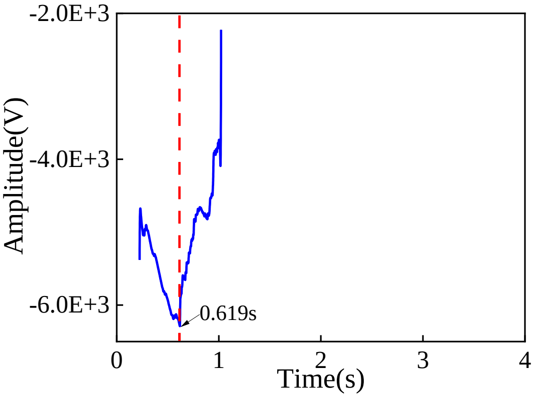


Fig. 19 The initial pick time of microseismic signals improved in this paper

In this paper, a segment of microseismic signals from field equipment operation is selected, with a sampling frequency of 2000Hz, as shown in Figure 16. The paper compares the first arrival points of microseismic signals using the improved STA/LTA method, the AIC method, and the method presented in this paper, with results depicted in Figures 17, 18, and 19, respectively. It can be observed from the figures that the first arrival point picked by the improved STA/LTA method is at 0.669s, which is 0.040s later than the manual picking. The AIC method picks the first arrival point at 0.608s, which is 0.018s earlier than the manual picking. Both methods exhibit significant errors in picking the first arrival points of microseismic signals in complex environments. In contrast, the method presented in this paper picks the first arrival point at 0.619s, which is 0.007s earlier than the manual picking, with the error falling within the acceptable range. Therefore, the method proposed in this paper can effectively pick the first arrival points of microseismic signals in noisy coal mine environments.

V. CONCLUSION

In this study, we introduce an innovative approach for determining the initial arrival times of P-waves in microseismic signals from coal mines. The manuscript commences with a review of established methods and underlying principles for P-wave onset detection, highlighting their prevalent use in the field. Subsequently, we address the limitations inherent in these traditional techniques, particularly the challenges associated with trigger threshold selection in the STA/LTA method and the time window determination in the AIC method. To this end, we propose a hybrid method that integrates an enhanced STA/LTA approach with the AIC method. This novel technique not only surmounts the aforementioned obstacles but also provides enhanced precision and commendable real-time capabilities. Our method holds significant potential for informing and enhancing microseismic monitoring initiatives within coal mining operations.

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